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PEDCo Environmental, Inc, Cincinnati, Ohio

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Compliance schedules previously presented in the first edition of a Technical Guide for Review and Evaluation of Compliance Schedules (Publication EPA 340/1-73-001a), have been reviewed and up-dated where required. Schedules for new industries are included and control systems are reviewed and evaluated based on information supplied by the manufacturers. Also included is a description of the compliance schedule format, summary schedules by type of control device, and an explanation of various factors which affect installations. Process descriptions, emission sources, emission characteristics, and commonly used control equipment are given for each industry studied.

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by

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1.0 INTRODUCTION

On August 14, 1971, the Administrator of the Environmental Protection Agency promulgated regulations in the Federal Register, 40 CFR Part 51, specifying minimum requirements for the State Air Quality Implementation Plans required by Section 110 of the Clean Air Act. As mandated by Section 110 and specified in these regulations, implementation plans must include emission limitations adequate to attain and maintain national ambient air quality standards and must require compliance schedules from all sources subject to the emission limitations. For sources in air quality control regions where the national primary standards are being exceeded, the schedules must provide for compliance as expeditiously as practicable; for sources in regions where only the secondary air quality standards are being exceeded, the schedules must provide for compliance within a reasonable period of time.

In July 1973 the Environmental Protection Agency, Division of Stationary Source Enforcement, published the first edition of a Technical Guide for Review and Evaluation of Compliance Schedules for Air Pollution Sources (Publication EPA-340/1-73-001a). The material presented herein has been prepared to update that publication. Certain schedules presented earlier have been modified, and schedules are included for new industries and control systems.

Manufacturers and users of air pollution control equipment supplied most of the information used to develop these schedules. Preliminary schedules based on PEDCo staff experience and manufacturers' data were subjected to engineering evaluation by the Industrial Gas Cleaning Institute. On the basis of these reviews, the schedules presented herein were developed.

As with the first edition, it is emphasized that these schedules should be considered as guidelines. Many factors may mitigate the proposed time scales. These can include on-site problems such as space limitations, inclement weather, and lack of needed utilities; logistical problems such as delays in equipment delivery caused by special orders, backlog of orders, or unavailability of large motors and/or fans; and design problems caused by lack of engineering data for some applications. To the limited extent possible, such factors were considered in preparation of the schedules.

Section 2.0 describes the compliance schedule format, presents summary schedules by type of control device, and describes the technical and economic contingencies that can affect control device installations. Section 3.0 presents brief process descriptions and describes emission sources and emission characteristics of the various industries. The types of control systems commonly used are identified; some of the problems encountered in achieving reliable, high-efficiency emissions control are briefly discussed; and sources of additional information are also listed. Time schedules are presented for installation of selected control systems. Section 4.0 describes the study approach and summarizes the supporting data on which the schedules are based.

2.0 COMPLIANCE SCHEDULE DEVELOPMENT

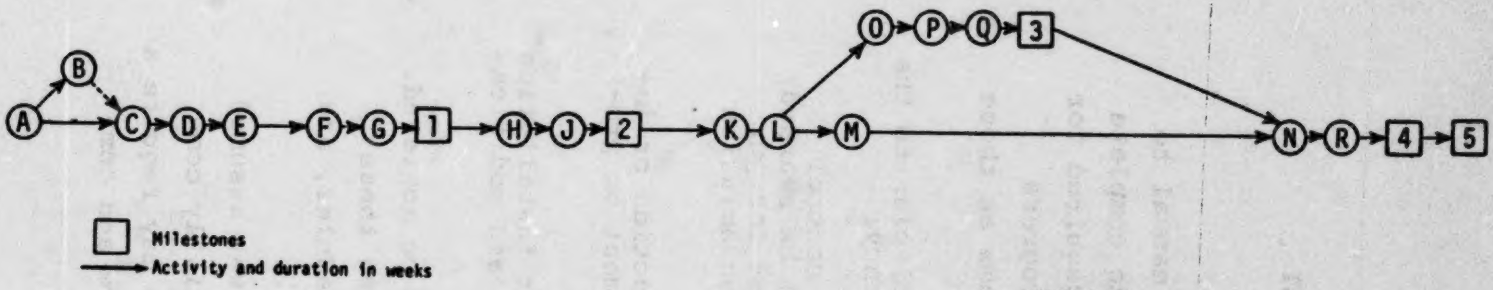
2.1 COMPLIANCE SCHEDULE FORMAT

Figure 2-1 depicts the chart used in this manual to identify the various steps generally required to complete installation of a control system and the time required for completion of such steps. The increments of progress (milestones) presented on this chart are the same as those defined in 40 CFR, Part 51:

1) Date of submittal of the final control plan to the appropriate air pollution control agency;
2) Date by which contracts for emission control systems or process modifications will be awarded; or date by which orders will be issued for purchase of component parts to accomplish emission control or process modification;
3) Date of initiation of on-site construction or installation of emission control equipment or process change;
4) Date by which on-site construction or installation of emission control equipment or process modification is to be completed; and
5) Date by which final compliance is to be achieved.

The major activities required for achieving these milestones, also shown on these compliance schedules, are described in Table 2-1.

In development of the time schedules, it was assumed that the steps prior to Milestone 1 are essentially complete. These very important preliminary steps may require a lengthy period of time, depending on the nature and com-



MILESTONES		ELAPSED TIME
1	Date of submittal of final control plan to appropriate agency.	______
2	Date of award of control device contract.	______
3	Date of initiation of on-site construction or installation of emission control equipment.	______
4	Date by which on-site construction or installation of emission control equipment is completed.	______
5	Date by which final compliance is achieved.	______

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 2-1. Compliance schedule chart.

Table 2-1. DESCRIPTION OF COMPLIANCE SCHEDULE ACTIVITIES

Activity code	Activity description	Details of activity
A-B	Conduct source tests	Emissions are estimated or measured to define need for control. Rate of emission, chemical composition, particle size, and other characteristics are determined to provide engineering design data.
A-C	Perform preliminary investigation	Feasibility studies are made to determine the best method for reducing emissions.
C-D	Evaluate control alternatives	Alternative methods of control are evaluated, budget estimates made, and a control plan is selected.
D-E	Commit funds for total program	Budget estimates are submitted and funds are applied for.
E-F	Prepare control plan and compliance schedule for agency review	Preliminary plans for controlling emissions are submitted to appropriate agencies for review.
F-G	Agency reviews and approves the plans	Control agency reviews plan and prepares comments. Recommended changes are made and agency approves plan.
G-1	Finalize plans and specification	The control system is specified in sufficient detail for suppliers and contractors to prepare bids. A final control plan summarizing this information is prepared for submittal to the agency.
1-H	Procure control device bids	Specifications for the control device are disseminated and bids from suppliers are requested.
H-J	Evaluate control device bids	Bids are evaluated and suppliers are selected.
J-2	Award control device contract	The successful bidder is notified and a contract is signed.
2-K	Prepare assembly drawings	The vendor prepares assembly drawings for the control device. For the smaller and more common types of devices, standard shop drawings applicable to several size ranges may be used with the appropriate dimensions underlined or otherwise indicated. For larger devices, it may be necessary to prepare drawings specifically for the project. The assembly drawings are mailed to the client for his approval before fabrication drawings are started.

Table 2-1 (Cont'd.). DESCRIPTION OF COMPLIANCE SCHEDULE ACTIVITIES

Activity code	Activity description	Details of activity
K-L	Review and approve assembly drawings	The client reviews the assembly drawings and gives approval to begin fabrication drawings. The client uses the assembly drawings to prepare engineering drawings.
L-M	Prepare fabrication drawings	Upon receipt of approval from client to proceed with construction of the control device, the vendor prepares fabrication or shop drawings for use in manufacturing and assembling the control equipment.
M-N	Fabricate control device	Based on fabrication drawings, the supplier fabricates major components of the device for shipment to the site. If the device is not too large, it can be completely fabricated and shipped as a package unit.
L-O	Prepare engineering drawings	Based on data from the vendor's drawings and on earlier engineering studies, the client (or his consultant) prepares architectural and mechanical drawings for any modifications and additions to the plant that are required to accommodate the emission control system.
O-P	Procure construction bids	The bid package is mailed to selected contractors. This package specifies the scope of work and the materials and includes the drawings. During this period, the contractors prepare bids for materials and labor to construct all duct work, piping, and utilities and for installation of the control device.
P-Q	Evaluate construction bids	The client or his consultant evaluates the bids and selects the contractor.
Q-3	Award construction contract	The selected contractor is notified and the contract is negotiated and signed.
3-N	Initiate on-site construction	Using the architectural and mechanical drawings, the contractor begins field work. He usually subcontracts various specialties such as electrical or duct work.
N-R	Install control device	The control device (or the components) arrives on site. The contractor should be prepared for installation and tie-in with other piping, duct work, and electrical switchgear. Field assembled units will arrive in sections for erection at the site. Internals such as catalysts, activated carbon, and bag filters are also installed during this time.
R-4	Complete construction and system tie-in	Tying the control device into the system requires shutdown of the process, scheduled for minimum disturbance of the operation. The contractor's responsibility usually ends when the client and the vendor's representative accept the construction as complete.
4-5	Perform startup, shakedown and emission testing	The process is brought back on-line and any unforeseen problems with the control system are resolved. Emissions testing may be performed to determine whether performance of the system is acceptable.

plexity of the control problem. Because many emission regulations have been in force for some time, however, it is assumed that much of this preliminary investigation is now complete. Where pilot plant investigations or further technology development are required, this phase of the work may still be under way.

During these initial steps the process owner must first determine the need for reducing emissions; this need may be evidenced by plant inspection, denial of an operating permit, or notice of violation. The owner must then evaluate the emissions and their relationship to the process to develop the information needed for an engineering evaluation of control alternatives. Feasibility studies of various control alternatives will include consideration of energy needs, potential additional environmental impacts (water, sludge, noise), and costs. On the basis of the feasibility studies the owner may select one or two control systems for further study and more exact cost estimates. He will then make budget appropriations and submit the control plan to the appropriate pollution control agency for review. Guided by agency comment, the owner can finalize the plans and initiate the control program.

The time schedules presented in this manual start at the point of finalizing control system plans and specifications for submission to the appropriate air pollution control agency (Activity G-1).

Table 2-2 identifies typical time increments required to complete the various activities on the schedule and the factors that influence these time requirements. The time ranges can vary considerably and are of limited usefulness in application to specific cases.

Table 2-2. EXPLANATION OF COMPLIANCE SCHEDULE ACTIVITIES

Activity	Comments
A-C	Preliminary investigations require 1 to 10 weeks to determine which sources require control. The time range depends on the number of vents, number and type of pollutants, and the methods for determining control needs.
A-B	An evaluation of emission parameters requires 2 to 8 weeks, depending on the need for and complexity of source testing.
C-D	Feasibility studies of alternative emission reduction plans require from 4 weeks to as much as 10 to 20 weeks, depending on the type of source, the number of alternatives studied, and the information available on control.
D-E	Time required for committing funds varies with the amount of money involved and the corporate approval steps required; typical increments are 2 to 10 weeks.
E-F	Proposing a preliminary control plan and scheduling review by the control agency typically requires 2 to 4 weeks. The time required will vary with the agency's needs.
F-G	Review by the control agency will require 2 to 8 weeks, depending on their backlog, staff availability, and complexity of the schedule.
G-1	Finalizing plans and specifications requires 2 to 6 weeks, depending on the magnitude and complexity of the project and the agency's comments.
1-H	A minimum of 4 weeks is required to procure bids on small jobs. A maximum of 12 weeks is allowed for large non-standard units, since initial vendor quotations frequently do not match bid specifications and further contacts with each bidder are required.
H-J	Evaluation of bids requires 2 to 5 weeks. Small, privately owned firms will require little time; in large corporations, bid evaluation often involves several departments and thus requires more time.
J-2	A minimum of 2 weeks is allocated for preparing final control plans and awarding contracts for the control device and major components. This activity takes longer in large corporations that require examination and approval of the contract by several departments.
2-K	Depending on the complexity and originality of the design, the time required by the vendor to submit assembly drawings showing dimensions, orientations, and loads could vary widely. Consultation with equipment suppliers indicates a range of 2 to 6 weeks.
K-L	Review and approval of assembly drawings requires 1 or 2 weeks. The longer period is required for any delay in approval as a result of revisions and modifications.

Table 2-2 (Cont'd.). EXPLANATION OF COMPLIANCE SCHEDULE ACTIVITIES

Activity	Comments
L-M	Normal time requirement for the vendor to prepare shop drawings for fabrication and assembly of the control device is 3 to 8 weeks. These figures are based on information supplied by control equipment suppliers.
N-R	For this activity, time is allocated primarily for installation of a shop-assembled (or modular) control device. For a field-erected unit, it represents the time required to complete the installation of components as they arrive on site. These installation times are based on data supplied by suppliers and substantiated by users.
M-N	On small control devices that can be shop-assembled, this activity represents fabrication, assembly of components, and delivery of the control unit to the site. On large field-erected control devices, time shown for this activity indicates fabrication and delivery of the first components to the site. Delivery of remaining components continues throughout the construction phase. Duration given for this activity, based on consultation with manufacturers of control devices, ranges from 14 to 30 weeks.
L-O	In this activity the client (or his consultant) prepares engineering drawing packages for use by the construction company for pouring foundations, installing structures, ductwork, electrical equipment, and any other items not supplied with the control device. These drawings also show the location and tie-in of the control device. Estimated engineering times range from 6 to 10 weeks.
O-P	Engineering drawings and specifications constitute the bulk of the construction bid document. A minimum of 2 weeks is allocated for obtaining bids from the contractors.
P-Q	Construction bids are evaluated and the successful bidder selected; 2 weeks is allowed for this activity.
Q-3	Construction contract is prepared. In large corporations, it is reviewed and approved by several departments before submission to the contractor. The procedure requires 2 to 3 weeks.
3-N	This activity consists primarily of site preparation; pouring of the foundation; erection of structural members; and installation of ductwork, controls, and auxiliary equipment. Typical requirement is 4 to 12 weeks.
N-R	For this activity, time is allocated primarily for installation of a shop-assembled (or modular) control device. For a field-erected unit, it represents the time required to complete installation of components as they arrive on site.
R-4	Tie-in requires 2 to 6 weeks. In large installations, where the process cannot be conventionally shut down at the end of the construction phase, longer times may be required to phase in the control device.
4-5	Time required for start-up, shakedown, and emission testing ranges from 2 weeks for a small and simple installation to about 6 to 10 weeks for a large, complicated system.

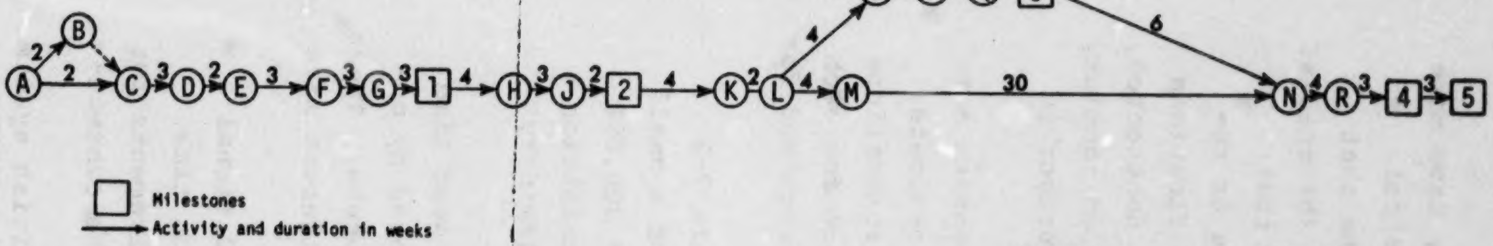
2.2 SUMMARY SCHEDULES BY CONTROL DEVICE

2.2.1 Simplified Control Device Schedules

Schedules for the expeditious installation of commonly used air pollution control devices are shown in Figures 2-2 through 2-18. These device-specific schedules supplement the process-specific schedules shown in Section 3.0. Although these schedules are necessarily more general than those presented in Section 3.0, they provide guidelines for evaluating or developing compliance schedules for processes not described in Section 3.0. The range of time shown for each increment indicates the expected variations. The schedule presents only the shortest time period for each increment.

These schedules are based on several sources of information. Delivery and installation times stated by control device suppliers are modified by personal experience and judgment and at times by comparison with the times required for recent installations. As discussed more fully in Section 2.3, many contingencies affect the compliance schedule, and delivery schedules must often be modified. Data developed from case histories also require qualification, since they often do not reflect expeditious schedules, either because the owner or the contractor does not vigorously pursue prompt installation or because the specifications are changed. In view of these types of delays, in addition to those caused by weather, labor problems, and the like, the schedules should be considered solely as guidelines.

These device-specific schedules are based on somewhat arbitrary breakpoints with respect to capacities; within each category of size range, (or capacity), significant variations in elapsed time can occur. Moreover, certain



MILESTONES

		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3	16
2	Date of award of control device contract.	12	25
3	Date of initiation of on-site construction or installation of emission control equipment.	30	43
4	Date by which on-site construction or installation of emission control equipment is completed.	59	72
5	Date by which final compliance is achieved.	62	75

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	4	2-5
C-D	Evaluate control alternatives	5	3-8
D-E	Commit funds for total progra	3	2-5
E-F	Prepare control plan and compliance schedule for agency	4	3-7
F-G	Agency reviews and approves plans	4	3-7
G-1	Finalize plans and specifications	4	3-7
1-H	Procure control device bids	5	4-8
H-J	Evaluate control device bids	4	3-6
J-2	Award control device contract	3	2-5
2-K	Prepare assembly drawings	5	4-7

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
K-L	Review and approve assembly drawings	3	2-5
L-M	Prepare fabrication drawings	6	4-8
M-N	Fabricate control devi	35	30-42
L-O	Prepare engineering drawings	6	4-8
O-P	Procure construction bids	5	4-7
P-Q	Evaluate construction bids	2	2-4
Q-3	Award construction contract	2	2-4
3-N	Initiate on-site construction	8	6-10
N-R	Install control device	6	4-7
R-4	Complete construction and system tie-in	4	3-5
4-5	Perform startup, shakedown, and emission testing	4	3-5

Figure 2-2. Schedule for installation of an electrostatic precipitator with capacity under 300,000 acfm.

factors influencing delivery and construction may have more effect on the final schedule than size of the control device. These factors include (a) special designs that require new fabrication drawings and procedures; (b) special materials of construction; (c) space limitations that necessitate unusual control system configurations or relocation of process equipment; (d) extensive modifications of the process; (e) type of contract -- erected, nonerected, or turnkey; and (f) type of unit -- shop-fabricated modular, or field-erected. These factors are described further in Section 2.3.

These schedules include time estimates for phases A to G of the overall compliance schedule. The time estimates are provided in the generalized schedules as approximations of the range of time requirements. The time range for each activity indicates the minimum and maximum time required for that activity.

2.2.1.1 Small Electrostatic Precipitator - Figure 2-2 shows the compliance schedule for installation of a small electrostatic precipitator with a capacity under 300,000 actual cubic feet per minute.[a] The minimum installation time is approximately 75 weeks, including a preliminary investigation period of 16 weeks.

Control device fabrication requires the longest time increment of from 30 to 42 weeks. This is followed by on-site construction time requirements of 6 to 10 weeks. These large time ranges result from order backlog, different size units, and different site conditions.

Installation of multiple units requires additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 9 to 12 weeks is estimated for each additional unit. This estimate includes the added time requirements for other activities.

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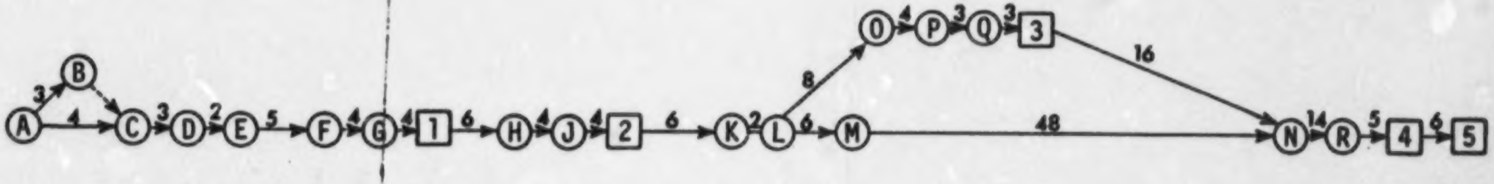
[a] The values in this report are expressed in British system of units. Appendix A presents the basic metric conversion factors.

The upgrading of a precipitator would mainly involve improvements in gas distribution or sectionalization, addition of new collector plates, modification of the rapping system, etc. The time required depends on the degree of upgrade. Time for preliminary investigation and vendor selection may not be needed for minor modifications. A major precipitator upgrade might require an entire new section in parallel or in series with the existing unit.

2.2.1.2 Large Electrostatic Precipitator - Figure 2-3 shows the compliance schedule for installation of a large electrostatic precipitator with capacity 300,000 cubic feet per minute or above. The minimum installation time is 123 weeks, including a preliminary investigation period of 22 weeks. A similar schedule would apply to either a conventional or hot (450-700°F) precipitator.

The longest time increment is control device fabrication which requires from 48 to 60 weeks. On-site construction requires 16 to 25 weeks. These large time ranges are due to different size units and to different site conditions.

Installation of multiple large precipitator units requires additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive delivery and erection of multiple units and allowing for the increased on-site construction period, an additional time increment of 18 to 24 weeks is estimated for each additional unit. This estimate also includes the minor additional time requirements for other activities.



☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4	22
2	Date of award of control device contract.	18	36
3	Date of initiation of on-site construction or installation of emission control equipment.	44	62
4	Date by which on-site construction or installation of emission control equipment is completed.	99	117
5	Date by which final compliance is achieved.	105	123

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	4	3-5
A-C	Perform preliminary investigation	4	4-6
C-D	Evaluate control alternatives	4	3-5
D-E	Commit funds for total program	2	2-4
E-F	Prepare control plan and compliance schedule for agency	6	5-7
F-G	Agency reviews and approves plans	6	4-7
G-1	Finalize plans and specifications	5	4-6
1-H	Procure control device bids	12	6-14
H-J	Evaluate control device bids	5	4-7
J-2	Award control device contract	4	4-6
2-K	Prepare assembly drawings	7	6-9
K-L	Review and approve assembly drawings	3	2-4
L-M	Prepare fabrication drawings	7	6-9
M-N	Fabricate control device	56	48-60
L-O	Prepare engineering drawings	10	8-11
O-P	Procure construction bids	5	4-6
P-Q	Evaluate construction bids	3	3-5
Q-3	Award construction contract	3	3-5
3-N	Initiate on-site construction	18	16-25
N-R	Install control device	17	14-19
R-4	Complete construction and system tie-in	8	5-9
4-5	Perform startup, shakedown, and emission testing	8	6-12

Figure 2-3. Schedule for installation of an electrostatic precipitator with capacity over 300,000 acfm.

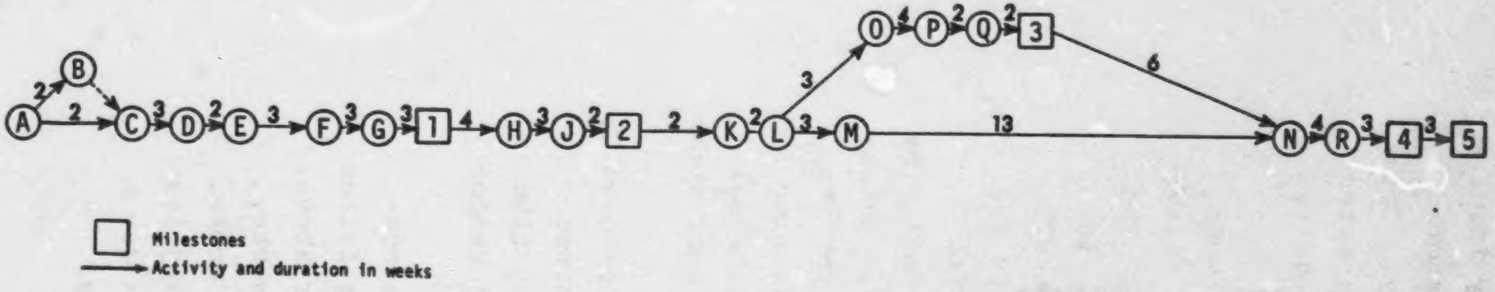
The upgrading of a precipitator would generally involve improvement of flow distribution, addition of collector plates, or modification of the ash handling facility. Total time requirement depends on the extent of upgrading; extensive modifications may entail more time than that required for the original installation.

2.2.1.3 Small Fabric Filter - Figure 2-4 shows the compliance schedule for installation of a small fabric filter with a capacity under 200,000 cubic feet per minute. The minimum installation time is approximately 55 weeks, including a preliminary investigation period of 16 weeks.

The installation of multiple fabric filter units requires additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 6 to 8 weeks is estimated for each additional unit. This estimate also includes the minor additional time requirements for other activities.

The upgrading of a fabric filter would mainly involve changes in fabric or cleaning mechanism. Time required depends on the degree of upgrade; in minor upgrading time may not be needed for preliminary investigation and vendor selection.

2.2.1.4 Large Fabric Filter - Figure 2-5 shows the compliance schedule for installation of a large fabric filter with a capacity of 200,000 cubic feet per minute or above. The minimum installation time is approximately 72 weeks, including a preliminary investigation period of 19 weeks. The initial period may be longer for new or novel applications of a fabric filter system or for applications requiring extensive preconditioning of the vent gases.

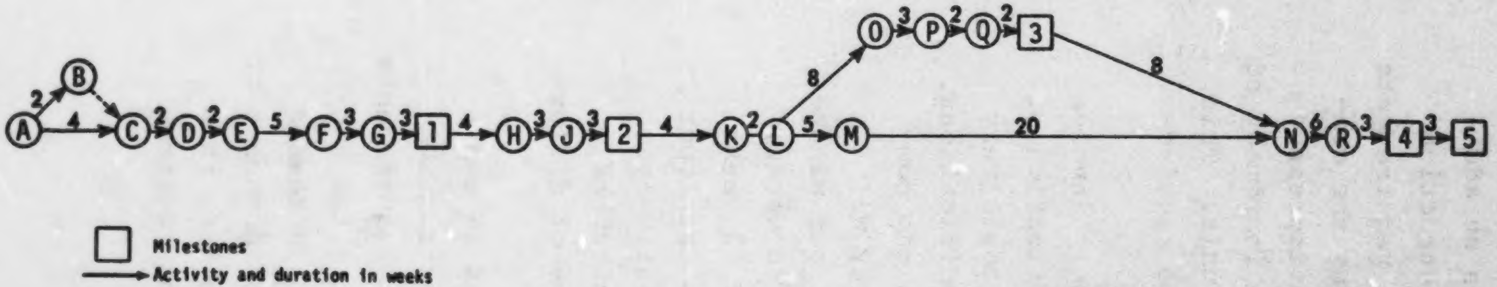


MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3	16
2	Date of award of control device contract.	12	25
3	Date of initiation of on-site construction or installation of emission control equipment.	27	40
4	Date by which on-site construction or installation of emission control equipment is completed.	40	53
5	Date by which final compliance is achieved.	43	56

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	4	2-5
C-D	Evaluate control alternatives	5	3-8
D-E	Commit funds for total program	3	2-5
E-F	Prepare control plan and compliance schedule for agency	4	3-7
F-G	Agency reviews and approves plans	4	3-7
G-1	Finalize plans and specifications	4	3-7
1-H	Procure control device bids	5	4-8
H-J	Evaluate control device bids	4	2-6
J-2	Award control device contract	3	2-5
2-K	Prepare assembly drawings	3	2-5

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
K-L	Review and approve assembly drawings	3	2-5
L-M	Prepare fabrication drawings	4	3-6
M-N	Fabricate control device	17	13-22
L-O	Prepare engineering drawings	5	3-7
O-P	Procure construction bids	5	4-7
P-Q	Evaluate construction bids	2	2-4
Q-3	Award construction contract	2	2-4
3-N	Initiate on-site construction	8	6-10
N-R	Install control device	6	4-7
R-4	Complete construction and system tie-in	4	3-5
4-5	Perform startup, shakedown, and emission testing	4	3-5

Figure 2-4. Schedule for installation of a fabric filter with capacity under 200,000 cfm.



MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3	19
2	Date of award of control device contract.	13	29
3	Date of initiation of on-site construction or installation of emission control equipment.	34	50
4	Date by which on-site construction or installation of emission control equipment is completed.	53	69
5	Date by which final compliance is achieved.	56	72

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	4	2-5
A-C	Perform preliminary investigation	6	4-9
C-D	Evaluate control alternatives	3	2-6
D-E	Commit funds for total program	3	2-3
E-F	Prepare control plan and compliance schedule for agency	8	5-10
F-G	Agency reviews and approves plans	4	3-7
G-1	Finalize plans and specifications	4	3-6
1-H	Procure control device bids	5	4-8
H-J	Evaluate control device bids	3	3-7
J-2	Award control device contract	4	3-6
2-K	Prepare assembly drawings	6	4-8

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
K-L	Review and approve assembly drawings	3	2-4
L-M	Prepare fabrication drawings	6	5-8
M-N	Fabricate control device	30	20-50
L-O	Prepare engineering drawings	10	8-12
O-P	Procure construction bids	4	3-5
P-Q	Evaluate construction bids	3	2-4
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	10	8-13
N-R	Install control device	8	6-10
R-4	Complete construction and system tie-in	4	3-5
4-5	Perform startup, shakedown, and emission testing	4	3-8

Figure 2-5. Schedule for installation of a fabric filter with capacity of 200,000 cfm or more.

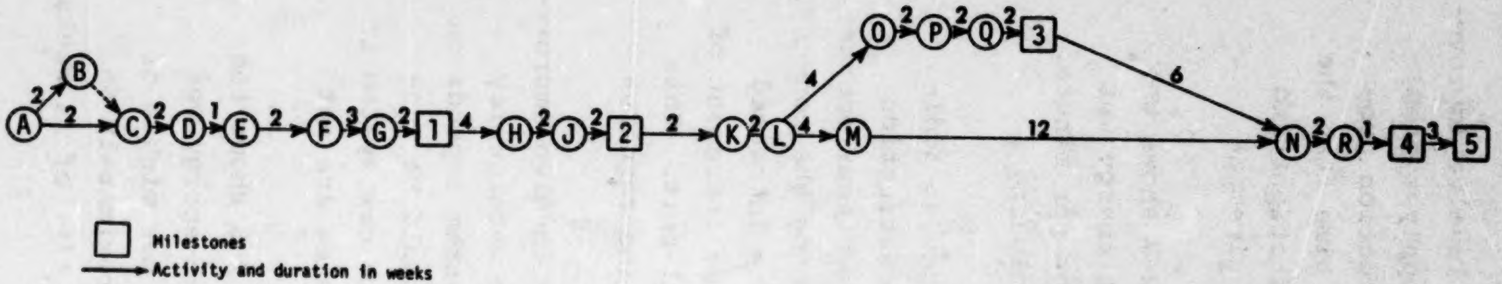
The installation of multiple units requires an additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 8 to 10 weeks is estimated for each additional unit. This estimate also includes the minor additional time requirements of other activities.

The upgrading of a fabric filter would mainly involve addition of filtration area (more bags) or modification of the bag cleaning system. The time requirement could vary widely depending on the nature and extent of modifications.

2.2.1.5 Low-Energy Scrubber - Figure 2-6 shows the compliance schedule for installation of a low-energy wet scrubber with capacity under 150,000 cubic feet per minute. The minimum installation time is approximately 46 weeks, including a preliminary investigation period of 12 weeks.

The time range for each activity indicates the lower and upper extremes for that increment. The relatively shorter span between the two limits for a wet scrubber indicates a small variation in installation time of different size low-energy wet scrubbers.

The installation of multiple units requires an additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 6 to 8 weeks is estimated for each additional unit. This estimate also includes the minor additional time requirements of other activities.



MILESTONES

		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2	12
2	Date of award of control device contract.	10	20
3	Date of initiation of on-site construction or installation of emission control equipment.	24	34
4	Date by which on-site construction or installation of emission control equipment is completed.	33	43
5	Date by which final compliance is achieved.	36	46

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	3	2-5
C-D	Evaluate control alternatives	3	2-5
D-E	Commit funds for total program	1	1-2
E-F	Prepare control plan and compliance schedule for agency	3	2-5
F-G	Agency reviews and approves plans	5	3-7
G-1	Finalize plans and specifications	3	2-5
1-H	Procure control device bids	5	4-8
H-J	Evaluate control device bids	2	2-4
J-2	Award control device contract	2	2-4
2-K	Prepare assembly drawings	3	2-4

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
K-L	Review and approve assembly drawings	3	2-4
L-M	Prepare fabrication drawings	7	4-9
M-N	Fabricate control device	15	12-24
L-O	Prepare engineering drawings	8	4-10
O-P	Procure construction bids	4	2-5
P-Q	Evaluate construction bids	2	2-3
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	7	6-10
N-R	Install control device	3	2-6
R-4	Complete construction and system tie-in	3	1-6
4-5	Perform startup, shakedown, and emission testing	4	3-5

Figure 2-6. Schedule for installation of a low-energy wet scrubber with capacity under 150,000 cfm.

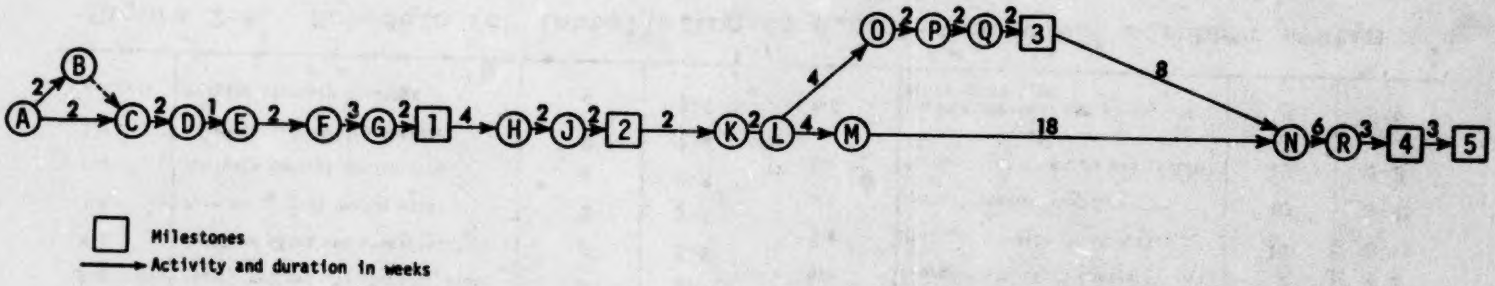
The upgrading of a scrubber would mainly involve improvement of the auxiliary systems (fan or water supply system) or modification of scrubber internals. The erection process for upgrading will probably require less time than the erection of a new unit, depending on site limitations and the extent of the modifications. The time requirement could range from a few weeks to many months.

2.2.1.6 Small High-Energy Scrubber - Figure 2-7 shows the compliance schedule for installation of a high-energy wet scrubber with capacity under 150,000 cubic feet per minute. The minimum installation time is 59 weeks, including a preliminary investigation period of 12 weeks.

The installation of multiple units requires an additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 8 to 10 weeks is estimated for each additional unit. This estimate also includes the minor additional time requirements of other activities.

The upgrading of a scrubber would mainly involve improvement of the auxiliary systems such as fans or water spray nozzles. The time required to upgrade the system depends on the nature and extent of modifications; it should be considerably less than that for installation of a new system if existing ductwork and water treatment facilities are not replaced.

2.2.1.7 Large High-Energy Scrubber - Figure 2-8 shows the compliance schedule for installation of a high-energy wet scrubber with capacity of 150,000 cubic feet per minute or above. The minimum installation time is approximately 66 weeks, including a preliminary investigation time of 14 weeks.

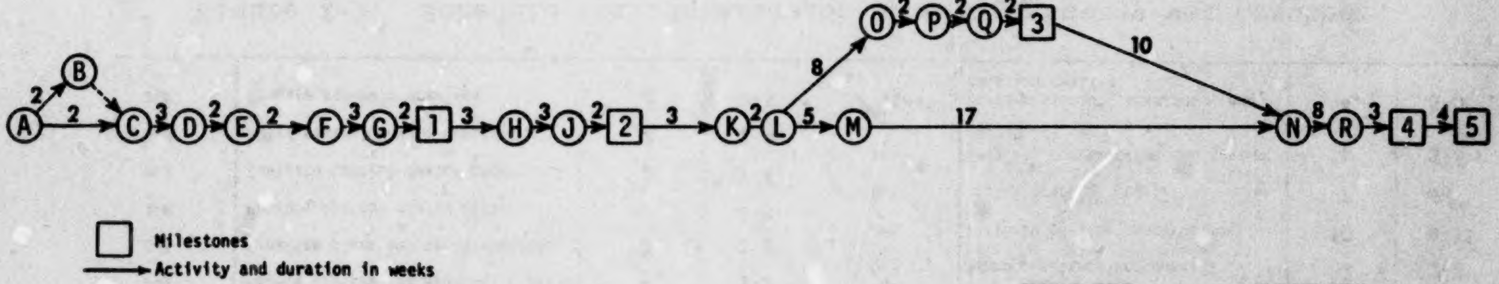


MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2	12
2	Date of award of control device contract.	10	20
3	Date of initiation of on-site construction or installation of emission control equipment.	24	34
4	Date by which on-site construction or installation of emission control equipment is completed.	45	55
5	Date by which final compliance is achieved.	48	58

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	3	2-5
C-D	Evaluate control alternatives	3	2-5
D-E	Commit funds for total program	1	1-2
E-F	Prepare control plan and compliance schedule for agency	3	2-5
F-G	Agency reviews and approves plans	5	3-7
G-1	Finalize plans and specifications	3	2-5
1-H	Procure control device bids	5	4-8
H-J	Evaluate control device bids	2	2-4
J-2	Award control device contract	2	2-4
2-K	Prepare assembly drawings	3	2-5

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
K-L	Review and approve assembly drawings	3	2-4
L-M	Prepare fabrication drawings	6	4-8
M-N	Fabricate control device	2	18-28
L-O	Prepare engineering drawings	6	4-10
O-P	Procure construction bids	4	2-5
P-Q	Evaluate construction bids	2	2-3
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	10	8-15
N-R	Install control device	7	6-9
R-4	Complete construction and system tie-in	4	3-5
4-5	Perform startup, shakedown, and emission testing	4	3-5

Figure 2-7. Schedule for installation of a high-energy wet scrubber with capacity under 150,000 cfm.



MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2	14
2	Date of award of control device contract.	10	22
3	Date of initiation of on-site construction or installation of emission control equipment.	29	41
4	Date by which on-site construction or installation of emission control equipment is completed.	50	62
5	Date by which final compliance is achieved.	54	66

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	3	2-4
C-D	Evaluate control alternatives	4	3-5
D-E	Commit funds for total program	2	2-3
E-F	Prepare control plan and compliance schedule for agency	3	2-5
F-G	Agency reviews and approves plans	5	3-7
G-1	Finalize plans and specifications	3	2-5
1-H	Procure control device bids	5	3-8
H-J	Evaluate control device bids	4	3-5
J-2	Award control device contract	2	2-4
2-K	Prepare assembly drawings	4	3-5
K-L	Review and approve assembly drawings	3	2-5
L-M	Prepare fabrication drawings	6	5-8
M-N	Fabricate control device	28	17-48
L-O	Prepare engineering drawings	9	8-12
O-P	Procure construction bids	4	2-5
P-Q	Evaluate construction bids	2	2-3
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	12	10-15
N-R	Install control device	10	8-15
R-4	Complete construction and system tie-in	15	3-8
4-5	Perform startup, shakedown, and emission testing	4	4-6

Figure 2-8. Schedule for installation of a high-energy wet scrubber system with capacity of 150,000 cfm or more..

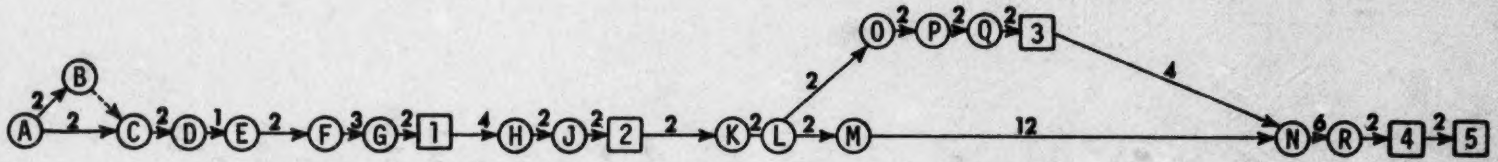
The installation of multiple units requires an additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 8 to 10 weeks is estimated for each additional unit. This estimate also includes the minor additional time requirements of other activities.

The upgrading of a scrubber would mainly involve replacement of throat sections, or installations of new water sprays and pumps, entrainment separators, or fans. The time required to upgrade the system could range from a few weeks to many months.

2.2.1.8 Afterburner - Figure 2-9 shows the compliance schedule for installation of an afterburner. The minimum installation time is 48 weeks, including a preliminary investigation period of 12 weeks.

The installation of multiple units requires an additional erection time (activity N-R) and also an additional on-site construction time (activity 3-N). Additional time requirements for other activites are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 8 to 10 weeks is estimated for each additional unit. This estimate also includes the minor additional time requirements of other activities.

The upgrading of an afterburner would mainly involve capability for operation at higher temperature or installation of parallel units. The time required to upgrade the system cannot be predicted accurately without definition of the modification.



☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2	12
2	Date of award of control device contract.	10	20
3	Date of initiation of on-site construction or installation of emission control equipment.	22	32
4	Date by which on-site construction or installation of emission control equipment is completed.	36	46
5	Date by which final compliance is achieved.	38	48

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	3	2-5
C-D	Evaluate control alternatives	3	2-5
D-E	Commit funds for total program	1	1-2
E-F	Prepare control plan and compliance schedule for agency	3	2-5
F-G	Agency reviews and approves plans	5	3-7
G-1	Finalize plans and specifications	3	2-5
1-H	Procure control device bids	5	4-8
H-J	Evaluate control device bids	2	2-4
J-2	Award control device contract	2	2-4
2-K	Prepare assembly drawings	3	2-4
K-L	Review and approve assembly drawings	3	2-4
L-M	Prepare fabrication drawings	3	2-5
M-N	Fabricate control device	14	12-18
L-O	Prepare engineering drawings	4	2-5
O-P	Procure construction bids	4	2-5
P-Q	Evaluate construction bids	2	2-3
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	6	4-7
N-R	Install control device	8	6-10
R-4	Complete construction and system tie-in	3	2-4
4-5	Perform startup, shakedown, and emission testing	3	2-4

Figure 2-9. Schedule for installation of an afterburner.

2.2.1.9 Package Adsorption System - Figure 2-10 shows the compliance schedule for installation of an adsorption system. The minimum installation time is 76 weeks, including a preliminary investigation period of 15 weeks.

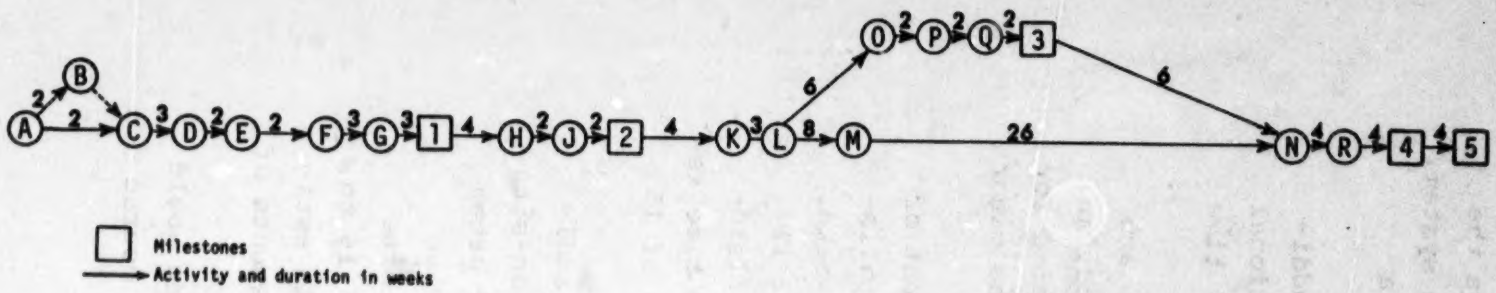
The installation of multiple units requires an additional erection time (activity N-R) and also an additional on-site construction time (activity 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of adsorption units and allowing for the increased on-site construction period, an additional time increment of 10 to 12 weeks is estimated for each additional unit. This estimate also includes the minor additional time requirements of other activities.

Upgrading may involve replacement of the adsorbent or installation of more beds to increase capacity. Installation times could range from a few weeks to about 15 weeks.

2.2.1.10 Adsorption System, Field-Erected - Figure 2-11 shows the compliance schedule for installation of a field-erected adsorption system. The minimum installation time is 85 weeks, including a preliminary investigation time of 15 weeks.

The installation of multiple units requires an additional fabrication and erection time and additional on-site construction time. Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 16 to 22 weeks is estimated for each additional unit. This estimate also includes the minor additional time requirements of other activities.

Time required for upgrading an adsorption system would be similar to that for package systems and would of course depend on the modification.

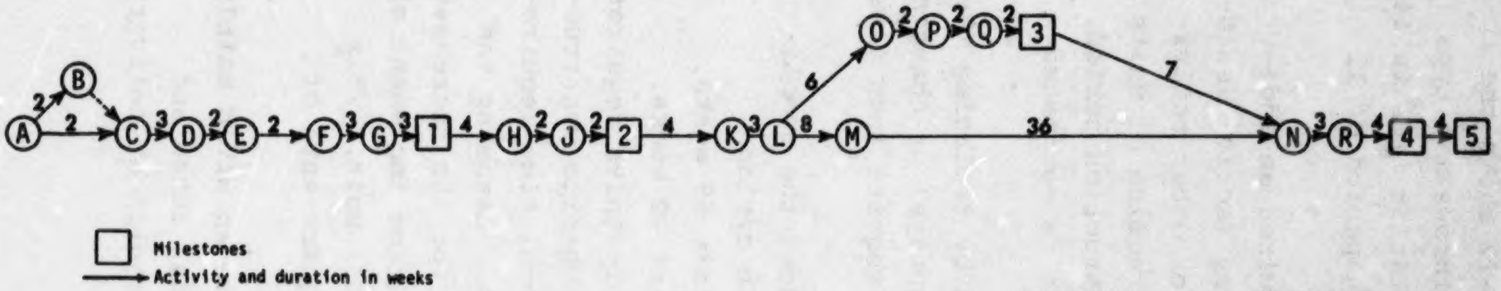


MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3	15
2	Date of award of control device contract.	11	23
3	Date of initiation of on-site construction or installation of emission control equipment.	30	42
4	Date by which on-site construction or installation of emission control equipment is completed.	60	72
5	Date by which final compliance is achieved.	64	76

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	3	2-4
C-D	Evaluate control alternatives	4	3-5
D-E	Commit funds for total program	2	2-3
E-F	Prepare control plan and compliance schedule for agency	3	2-5
F-G	Agency reviews and approves plans	5	3-7
G-1	Finalize plans and specifications	4	3-6
1-H	Procure control device bids	6	4-7
H-J	Evaluate control device bids	3	2-5
J-2	Award control device contract	3	2-5
2-K	Prepare assembly drawings	6	4-7

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
K-L	Review and approve assembly drawings	4	3-6
L-M	Prepare fabrication drawings	10	8-12
M-N	Fabricate control device	30	26-32
L-O	Prepare engineering drawings	8	6-9
O-P	Procure construction bids	4	2-5
P-Q	Evaluate construction bids	2	2-3
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	7	6-9
N-R	Install control device	5	4-7
R-4	Complete construction and system tie-in	5	4-6
4-5	Perform startup, shakedown, and emission testing	5	4-6

Figure 2-10. Schedule for installation of a packaged adsorption system, including field-erected distillation unit.



MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3	15
2	Date of award of control device contract.	11	23
3	Date of initiation of on-site construction or installation of emission control equipment.	30	42
4	Date by which on-site construction or installation of emission control equipment is completed.	69	81
5	Date by which final compliance is achieved.	73	85

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	3	2-4
C-D	Evaluate control alternatives	4	3-5
D-E	Commit funds for total program	2	2-3
E-F	Prepare control plan and compliance schedule for agency	3	2-5
F-G	Agency reviews and approves plans	5	3-7
G-1	Finalize plans and specifications	4	3-6
1-H	Procure control device bids	6	4-7
H-J	Evaluate control device bids	3	2-5
J-2	Award control device contract	3	2-5
2-K	Prepare assembly drawings	3	4-7

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
K-L	Review and approve assembly drawings	4	3-6
L-M	Prepare fabrication drawings	10	8-12
M-N	Fabricate control device	40	36-42
L-O	Prepare engineering drawings	8	6-9
O-P	Procure construction bids	4	2-5
P-Q	Evaluate construction bids	2	2-3
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	9	7-12
N-R	Install control device	4	3-5
R-4	Complete construction and system tie-in	5	4-6
4-5	Perform startup, shakedown, and emission testing	5	4-6

Figure 2-11. Schedule for installation of a field-erected adsorption system, including distillation unit.

2.2.1.11 High Energy Air Filter - Figure 2-12 shows the compliance schedule for installation of a fibrous mat type high-energy air filter. The minimum installation time is 44 weeks, including a preliminary investigation period of 12 weeks.

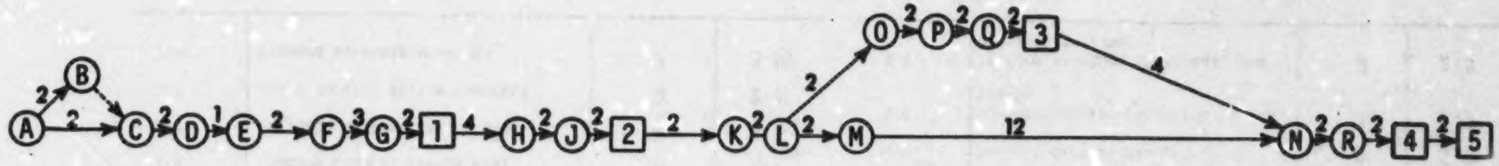
The installation of multiple units requires an additional erection and on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are minor. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 3 to 4 weeks is estimated for each additional unit.

These air filter units may be upgraded by replacing the filtering medium or mat, installing water sprays, or changing the mat speed. These modifications do not require much time after initial planning has been completed.

2.2.1.12 Multiple Cyclone - Figure 2-13 shows the compliance schedule for installation of a multiple cyclone. The minimum installation time is approximately 69 weeks, including a preliminary investigation time of 22 weeks.

The installation of cyclones on multiple units requires an additional erection time and additional on-site construction time (activites N-R and 3-N). Additional time requirements for other activites are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 6 to 8 weeks is estimated for each additional unit. This estimate also allows for the added time requirements of other activities.

The upgrading of a multiple cyclone system would mainly involve replacement or repair of the internal tubes and would require 1 to 4 weeks in addition to equipment delivery.



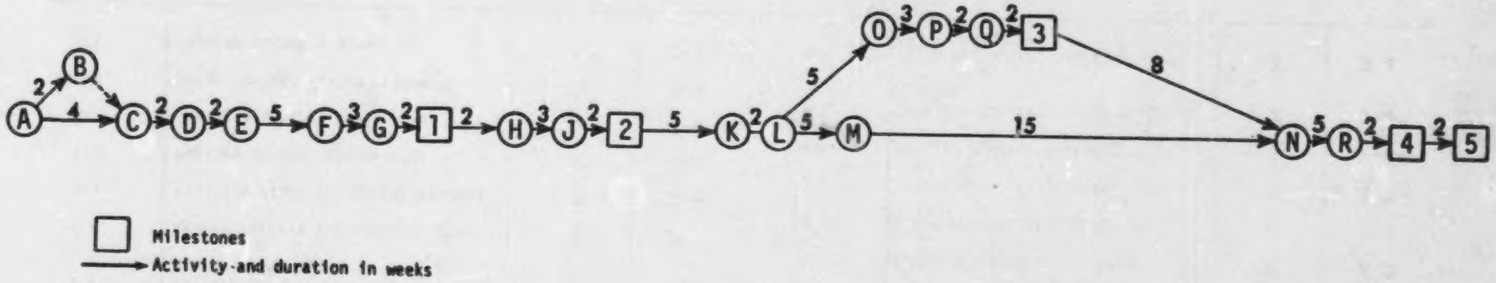
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2	12
2	Date of award of control device contract.	10	20
3	Date of initiation of on-site construction or installation of emission control equipment.	22	32
4	Date by which on-site construction or installation of emission control equipment is completed.	32	42
5	Date by which final compliance is achieved.	34	44

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	3	2-5
C-D	Evaluate control alternatives	3	2-5
D-E	Commit funds for total program	1	1-2
E-F	Prepare control plan and compliance schedule for agency	3	2-5
F-G	Agency reviews and approves plans	5	3-7
G-1	Finalize plans and specifications	3	2-5
1-H	Procure control device bids	5	4-8
H-J	Evaluate control device bids	2	2-4
J-2	Award control device contract	2	2-4
2-K	Prepare assembly drawings	3	2-4
K-L	Review and approve assembly drawings	2	2-4
L-M	Prepare fabrication drawings	3	2-5
M-N	Fabricate control device	14	12-18
L-O	Prepare engineering drawings	4	2-5
O-P	Procure construction bids	4	2-5
P-Q	Evaluate construction bids	2	2-3
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	6	4-7
N-R	Install control device	3	2-4
R-4	Complete construction and system tie-in	3	2-4
4-5	Perform startup, shakedown, and emission testing	3	2-4

Figure 2-12. Schedule for installation of a high-energy air filter unit.



MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2	18
2	Date of award of control device contract.	9	25
3	Date of initiation of on-site construction or installation of emission control equipment.	28	44
4	Date by which on-site construction or installation of emission control equipment is completed.	43	59
5	Date by which final compliance is achieved.	45	61

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	4	2-5
A-C	Perform preliminary investigation	6	4-9
C-D	Evaluate control alternatives	3	2-6
D-E	Commit funds for total program	2	2-3
E-F	Prepare control plan and compliance schedule for agency	8	5-10
F-G	Agency reviews and approves plans	4	3-7
G-1	Finalize plans and specifications	4	2-6
1-H	Procure control device bids	4	2-6
H-J	Evaluate control device bids	4	3-6
J-2	Award control device contract	3	2-5
2-K	Prepare assembly drawings	7	5-10
K-L	Review and approve assembly drawings	3	2-4
L-M	Prepare fabrication drawings	7	5-9
M-N	Fabricate control device	20	15-28
L-O	Prepare engineering drawings	6	5-9
O-P	Procure construction bids	4	3-7
P-Q	Evaluate construction bids	3	2-4
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	10	8-15
N-R	Install control device	6	5-8
R-4	Complete construction and system tie-in	4	2-7
4-5	Perform startup, shakedown, and emission testing	3	2-5

Figure 2-13. Schedule for installation of a multiple cyclone.

Final system shakedown and checking would require 2 to 5 weeks.

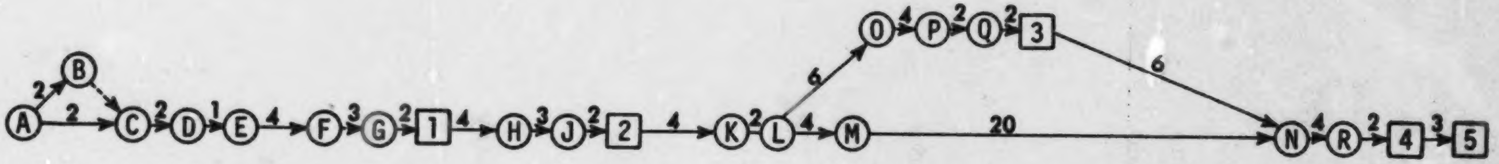
Installation time for a multiple cyclone is fairly independent of the flow of gas to be cleaned. Although installation of the larger units requires use of a higher-capacity crane and other larger-scale erection equipment, the total installation time remains unchanged.

2.2.1.13 Mist Eliminator - Figure 2-14 shows the compliance schedule for installation of a mist eliminator. The minimum installation time is approximately 62 weeks, including a preliminary investigation period of 14 weeks.

The installation of multiple units requires an additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 5 to 7 weeks is estimated for each additional unit. This estimate also allows for the added time requirements of other activites.

The upgrading of a mist eliminator system would mainly involve installation of additional eliminator sections in series. Time required to upgrade the system naturally depends on the degree of modification. Time for preliminary investigation and vendor selection may not be needed for minor modifications.

Installation time for a mist eliminator is fairly independent of the gas volume. Although installation of larger units requires the use of larger-capacity erection equipment, the total installation time remains unchanged.



☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2	14
2	Date of award of control device contract.	11	23
3	Date of initiation of on-site construction or installation of emission control equipment.	31	43
4	Date by which on-site construction or installation of emission control equipment is completed.	47	59
5	Date by which final compliance is achieved.	50	62

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	3	2-5
C-D	Evaluate control alternatives	4	2-8
D-E	Commit funds for total program	1	1-2
E-F	Prepare control plan and compliance schedule for agency	5	4-7
F-G	Agency reviews and approves plans	5	3-7
G-1	Finalize plans and specifications	3	2-5
1-H	Procure control device bids	5	4-8
H-J	Evaluate control device bids	4	3-6
J-2	Award control device contract	3	2-5
2-K	Prepare assembly drawings	5	4-7
K-L	Review and approve assembly drawings	3	2-5
L-M	Prepare fabrication drawings	6	4-8
M-N	Fabricate control device	22	20-26
L-O	Prepare engineering drawings	7	6-9
O-P	Procure construction bids	5	4-8
P-Q	Evaluate construction bids	3	2-5
Q-3	Award construction contract	2	2-4
3-N	Initiate on-site construction	7	6-9
N-R	Install control device	5	4-7
R-4	Complete construction and system tie-in	3	2-4
4-5	Perform startup, shakedown, and emission testing	4	3-7

Figure 2-14. Schedule for installation of a mist eliminator system.

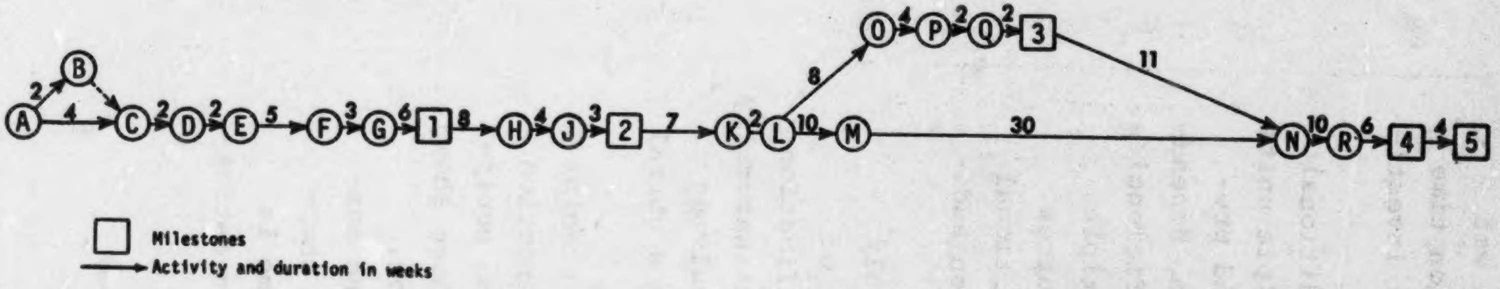
2.2.1.14 Wet Electrostatic Precipitator - Figure 2-15 shows the compliance schedule for installation of a wet electrostatic precipitator. The minimum installation time is approximately 106 weeks, including a preliminary investigation period of 22 weeks.

Installation of multiple units requires an additional time for erection (activity N-R). In case of multiple units of different sizes and designs, vendor selection and preliminary investigation will require additional time, depending on site conditions, unit sizes, and control efficiencies. Time requirement for installation of identical multiple units depends on the availability of erection resources. Assuming the consecutive erection of units, an additional time increment of 6 to 8 weeks is estimated for each additional identical unit.

The upgrading of a wet precipitator would mainly involve improvement of flow distribution, addition of collector plates, change of spray nozzles, or modification of the sludge removal system. The time requirement naturally depends on the extent of upgrading. Upgrading involving extensive modifications may require more time than a normal project, since it may entail some dismantling.

The installation of larger wet electrostatic precipitators involves an additional field assembly and erection time as well as the use of higher-capacity erection equipment. The various time increments may approach those shown in Figure 2-3 for a large conventional precipitator.

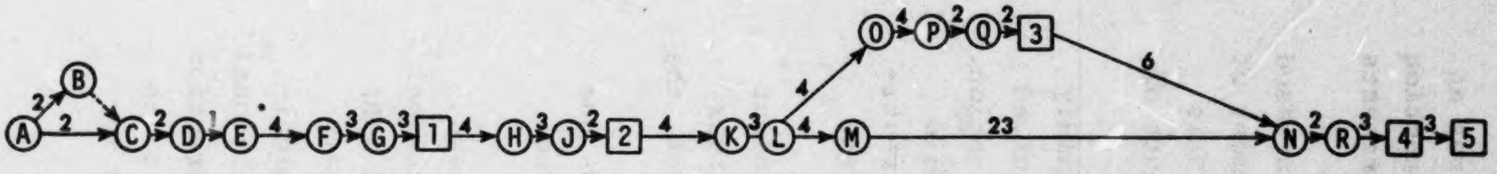
2.2.1.15 Package CO Boiler - Figure 2-16 shows the compliance schedule for installation of a package or shop-assembled CO boiler. The minimum installation time is approximately 66 weeks, including a preliminary investigation period of 15 weeks.



MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6	22
2	Date of award of control device contract.	21	37
3	Date of initiation of on-site construction or installation of emission control equipment.	46	62
4	Date by which on-site construction or installation of emission control equipment is completed.	86	102
5	Date by which final compliance is achieved.	90	106

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	4	2-5
A-C	Perform preliminary investigation	6	4-9
C-D	Evaluate control alternatives	3	2-6
D-E	Commit funds for total program	2	2-3
E-F	Prepare control plan and compliance schedule for agency	8	5-10
F-G	Agency reviews and approves plans	4	3-7
G-1	Finalize plans and specifications	7	6-9
1-H	Procure control device bids	10	8-12
H-J	Evaluate control device bids	5	4-7
J-2	Award control device contract	4	3-5
2-K	Prepare assembly drawings	10	7-15
K-L	Review and approve assembly drawings	2	2-4
L-M	Prepare fabrication drawings	13	10-17
M-N	Fabricate control device	35	30-40
L-O	Prepare engineering drawings	10	8-11
O-P	Procure construction bids	5	4-9
P-Q	Evaluate construction bids	3	2-5
Q-3	Award construction contract	3	2-5
3-N	Initiate on-site construction	14	11-22
N-R	Install control device	16	10-18
R-4	Complete construction and system tie-in	7	6-10
4-5	Perform startup, shakedown, and emission testing	6	4-10

Figure 2-15. Schedule for installation of a wet electrostatic precipitator.



☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3	15
2	Date of award of control device contract.	12	24
3	Date of initiation of on-site construction or installation of emission control equipment.	31	43
4	Date by which on-site construction or installation of emission control equipment is completed.	51	63
5	Date by which final compliance is achieved.	54	66

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-4
A-C	Perform preliminary investigation	3	2-5
C-D	Evaluate control alternatives	4	2-8
D-E	Commit funds for total program	1	1-2
E-F	Prepare control plan and compliance schedule for agency	5	4-7
F-G	Agency reviews and approves plans	5	3-7
G-1	Finalize plans and specifications	4	3-7
1-H	Procure control device bids	5	4-8
H-J	Evaluate control device bids	4	3-6
J-2	Award control device contract	3	2-4
2-K	Prepare assembly drawings	6	4-7

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
K-L	Review and approve assembly drawings	4	3-5
L-M	Prepare fabrication drawings	6	4-8
M-N	Fabricate control device	7	3-30
L-O	Prepare engineering drawings	6	4-8
O-P	Procure construction bids	5	4-7
P-Q	Evaluate construction bids	3	2-4
Q-3	Award construction contract	2	2-4
3-N	Initiate on-site construction	7	6-9
N-R	Install control device	3	2-4
R-4	Complete construction and system tie-in	4	3-5
4-5	Perform startup, shakedown, and emission testing	4	3-5

Figure 2-16. Schedule for installation of a package CO boiler.

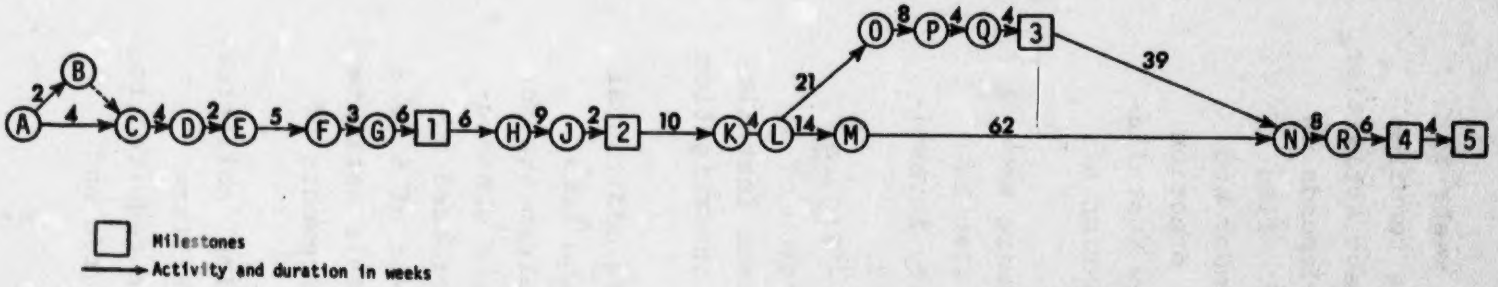
The installation of multiple package units requires an additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased on-site construction period, an additional time increment of 4 to 5 weeks is estimated for each additional unit. This estimate will also allow for the added time requirements of other activities.

The upgrading of a package boiler system would mainly involve modifications of the burner system. Time required to upgrade the system depends on the degree of modification. If only burner tips are changed, the delivery time would determine the time schedule. Time for preliminary investigation and vendor selection would be greatly reduced for minor modifications.

Installation time for a package boiler is independent of the unit size. Even though installation of the larger units requires use of large capacity erection equipment, the total installation time remains unchanged.

2.2.1.16 CO Boiler, Field-Erected - Figure 2-17 shows the compliance schedule for a field-erected CO boiler. The minimum installation time is approximately 149 weeks, including a preliminary investigation period of 24 weeks.

The installation of multiple units requires additional time for fabrication and erection (activities M-N and N-R) and for on-site construction time (activity 3-N). Additional time requirements for other activities are insignificant. The additional time requirement for each additional unit depends on the availability of fabrication and erection resources. Assuming the consecutive erection of units, an additional time increment of 8 weeks will be required for



MILESTONES		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6	24
2	Date of award of control device contract.	23	41
3	Date of initiation of on-site construction or installation of emission control equipment.	74	92
4	Date by which on-site construction or installation of emission control equipment is completed.	127	145
5	Date by which final compliance is achieved.	131	149

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	4	2-5
A-C	Perform preliminary investigation	6	4-9
C-D	Evaluate control alternatives	7	4-10
D-E	Commit funds for total program	2	2-3
E-F	Prepare control plan and compliance schedule for agency	7	5-10
F-G	Agency reviews and approves plans	6	3-9
G-1	Finalize plans and specifications	7	6-10
1-H	Procure control device bids	9	6-12
H-J	Evaluate control device bids	10	9-14
J-2	Award control device contract	3	2-4
2-K	Prepare assembly drawings	12	10-16

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
K-L	Review and approve assembly drawings	5	4-8
L-M	Prepare fabrication drawings	16	14-20
M-N	Fabricate control device	65	62-76
L-O	Prepare engineering drawings	23	21-29
O-P	Procure construction bids	9	8-12
P-Q	Evaluate construction bids	5	4-7
Q-3	Award construction contract	4	4-6
3-N	Initiate on-site construction	42	39-50
N-R	Install control device	10	8-13
R-4	Complete construction and system tie-in	8	6-10
4-5	Perform startup, shakedown, and emission testing	6	4-9

Figure 2-17. Schedule for installation of a field-erected CO boiler.

each additional unit. The estimate of 12 to 14 weeks for each additional unit incorporates the added time requirements for fabrication, erection, and other project activities.

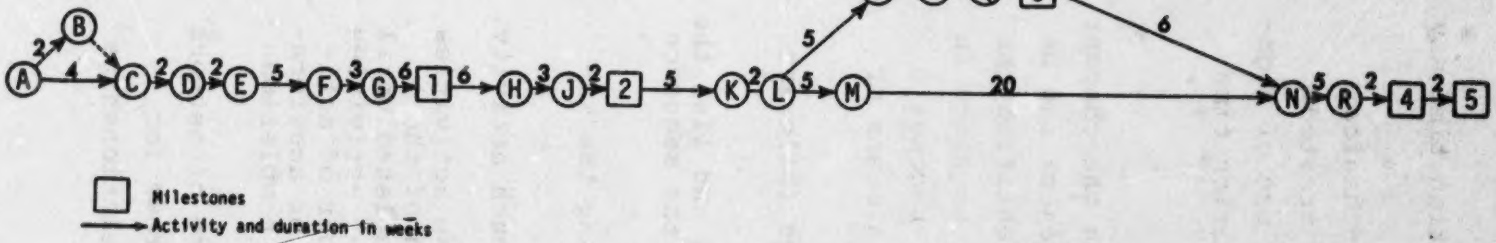
Time required to upgrade an existing unit depends on the amount of fabrication and sitework involved. Time needed for preliminary investigation and for vendor and contractor selection may remain unchanged. The erection time for upgrading may be more than that for new installations, since removal of old equipment and limitation of working space may cause delays.

Installation of larger CO boilers will require more time; the erection sequence and procedures may also be different for these units. Times for preliminary investigation and vendor selection may remain unchanged.

2.2.1.17 Combination Wet Mechanical Collector - Figure 2-18 shows the compliance schedule for installation of a combination wet mechanical collector. The minimum installation time is 74 weeks, including a preliminary investigation time of 22 weeks.

The installation of multiple units requires additional erection time and additional on-site construction time (activities N-R and 3-N). Additional time requirements for other activities are insignificant. Assuming the consecutive erection of units and allowing for the increased onsite construction period, an additional increment of 6 to 8 weeks is estimated for each additional unit. This estimate also allows for the minor additional time requirements of other activities.

The upgrading of a combination wet mechanical collector system would mainly involve modification of auxiliary systems such as water sprays or fans. The time required to upgrade the system naturally depends on the degree and



MILESTONES

		ELAPSED TIME FROM G, WEEKS	ELAPSED TIME FROM A, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6	22
2	Date of award of control device contract.	17	33
3	Date of initiation of on-site construction or installation of emission control equipment.	36	52
4	Date by which on-site construction or installation of emission control equipment is completed.	56	72
5	Date by which final compliance is achieved.	58	74

Activity designation	Activity description	Typical duration, weeks	Duration range, weeks
A-B	Conduct source tests	3	2-3
A-C	Perform preliminary investigation	6	4-6
C-D	Evaluate control alternatives	3	2-4
D-E	Commit funds for total program	2	2-3
E-F	Prepare control plan and compliance schedule for agency	7	5-8
F-G	Agency reviews and approves plans	4	3-6
G-1	Finalize plans and specifications	7	6-9
1-H	Procure control device bids	8	6-10
H-J	Evaluate control device bids	4	3-6
J-2	Award control device contract	3	2-5
2-K	Prepare assembly drawings	6	5-8
K-L	Review and approve assembly drawings	3	2-4
L-M	Prepare fabrication drawings	7	5-9
M-N	Fabricate control device	24	20-28
L-O	Prepare engineering drawings	6	5-9
O-P	Procure construction bids	4	3-7
P-Q	Evaluate construction bids	3	2-4
Q-3	Award construction contract	2	2-3
3-N	Initiate on-site construction	12	8-15
N-R	Install control device	6	5-8
R-4	Complete construction and system tie-in	3	2-4
4-5	Perform startup, shakedown, and emission testing	4	2-7

Figure 2-18. Schedule for installation of a combination wet mechanical collector.

extent of modification. Preliminary investigation time may not be needed for minor modifications.

Installation time for a combination wet mechanical collector is independent of the gas flow to be treated. Although installation of larger units requires use of high-capacity erection equipment, the total installation time remains unchanged.

2.2.2 Critical Path Method

The Critical Path Method (CPM) is based on the concept of network logic. By use of this logic any project can be represented in a network form. The network identifies the relationships among activities and the logical sequence in which they can be performed. The network thus becomes a basis for project planning and scheduling and a means of monitoring progress.

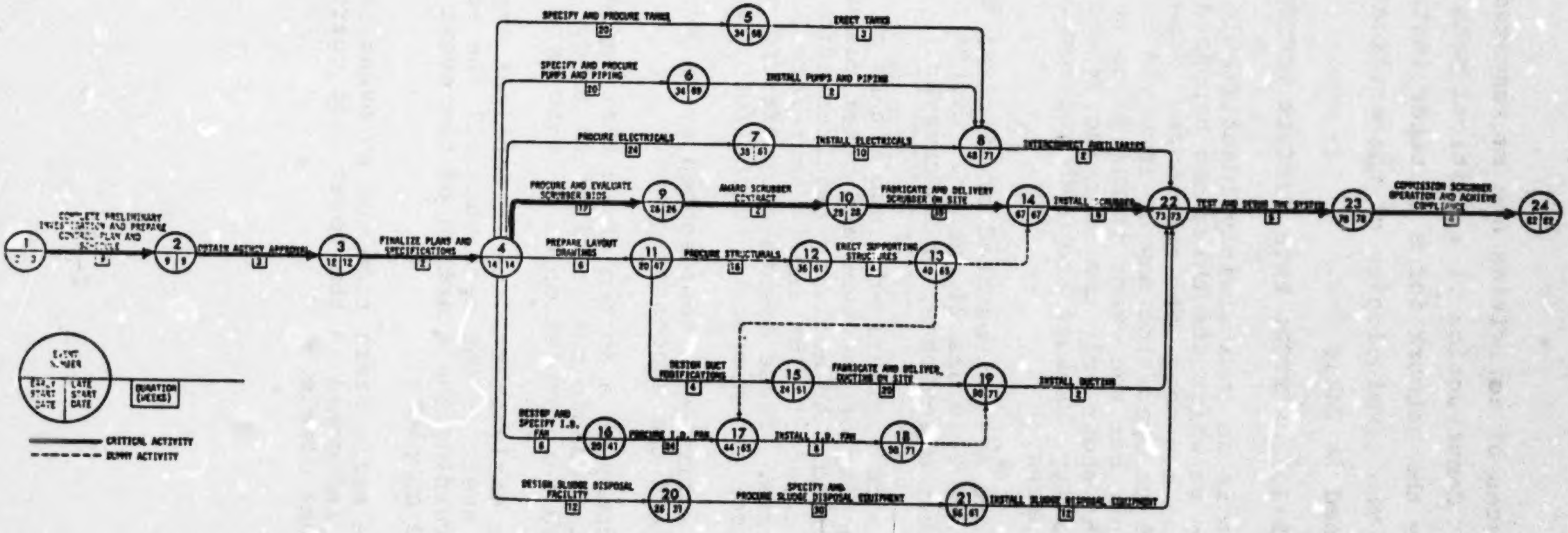
Development of the network consists of the following steps:

- Develop the project structure. Visualize and list the different activities to be performed and the sequence in which they can be performed.
- Construct the activity network representing the sequence and relationship of activities.
- Determine and assign time estimates for each activity.
- Determine the Critical Path - Identify the activities that are crucial to the timely completion of the project (i.e. the next step cannot be completed until the previous one is done). These critical activities form a small percentage of the total number of activities in the entire project. Any delay or acceleration of these activities will affect the completion date of the project.

The activity network is constructed by use of network logic and some simple conventions, such as arrows for activities and circles for events; the interrelationships and the sequences of activities are represented in the form of a network. Construction of a critical path network is illustrated by the network for a scrubber installation in Figure 2-19. The terminologies of the critical path network are defined in Table 2-3.

Table 2-3. CRITICAL PATH NETWORK TERMINOLOGIES

Event:	This is an inexplicitly identifiable point in time at which something has happened or a situation has come into existence. Some amount of work or operation may be involved in reaching an event, but the event itself takes no time. An event shows only the starting or end point of any activity. Events are numbered for reference purposes. Events are represented by circles; the network in Figure 2-19 has 24 events. Events are also called nodes, milestones, or benchmarks.
Activity:	This is a clearly definable task to which a known quantity of manpower and other resources must be applied. An activity requires effort applied over a period of time and is therefore bounded by two events. These events are referred to as predecessor and successor events for the activity. An activity is represented by an arrow directed toward the successor event.
Dummy:	A dummy is a dotted arrow that represents an interrelationship but involves no time. Dummies are used for completion of a logic in a network.
Early Start Date:	The early start date or earliest expected time of an event is the date when all the activities constraining the starting of the event in question are completed. The early start time for an event in Figure 2-19 is indicated in the lower left quarter of the event circle.



COMPLETE PRELIMINARY INVESTIGATION AND PREPARE CONTROL PLAN AND SCHEDULE
OBTAIN AGENCY APPROVAL
FINALIZE PLANS AND SPECIFICATIONS
SPECIFY AND PROCURE TANKS
ERECT TANKS
SPECIFY AND PROCURE PUMPS AND PIPING
INSTALL PUMPS AND PIPING
PROCURE ELECTRICALS
INSTALL ELECTRICALS
INTERCONNECT AUXILIARIES
PROCURE AND EVALUATE SCRUBBER BIDS
AWARD SCRUBBER CONTRACT
FABRICATE AND DELIVERY SCRUBBER ON SITE
INSTALL SCRUBBER
TEST AND DEBUG THE SYSTEM
COMMISSION SCRUBBER OPERATION AND ACHIEVE COMPLIANCE
PREPARE LAYOUT DRAWINGS
PROCURE STRUCTURALS
ERECT SUPPORTING STRUCTURES
DESIGN DUCT MODIFICATIONS
FABRICATE AND DELIVER, DUCTING ON SITE
INSTALL DUCTING
DESIGN AND SPECIFY I.D. FAN
PROCURE I.D. FAN
INSTALL I.D. FAN
DESIGN SLUDGE DISPOSAL FACILITY
SPECIFY AND PROCURE SLUDGE DISPOSAL EQUIPMENT
INSTALL SLUDGE DISPOSAL EQUIPMENT
1
2
9 9
3
12 12
4
14 14
5
34 66
6
34 69
7
38 61
8
48 71
9
26 26
10
28 28
11
20 47
12
36 61
13
40 65
14
67 67
15
24 51
16
20 41
17
44 65
18
50 71
19
50 71
20
26 31
21
56 61
22
73 73
23
78 78
24
82 82
20
3
20
2
24
10
2
17
2
6
16
4
6
4
26
2
6
12
30
12
EVENT NUMBER
EARLY START DATE
LATE START DATE
DURATION (WEEKS)
CRITICAL ACTIVITY
DUMMY ACTIVITY

Figure 2-19. Critical path schedule for scrubber installation.

Late Start Date:	The late start date or latest allowable time is that by which an event should occur if slippage of the event schedule is to be avoided. The late start date for an event in Figure 2-19 is indicated in the lower right quarter of the event circle.
Slack:	The slack or float is a difference between the earliest expected time and latest allowable time; it represents flexibility. This is a range of time over which an activity can take place without influencing the project completion date.
Critical Path:	The longest time path through a network is called the critical path, which represents the least time for achieving the objective without crashing. The activities on the critical path are called critical activities. The critical activities have no slack and are generally shown by a heavy line.

Each event circle in the diagram contains the event number and the time limits. The event number is in the upper half of the circle; the early start date is in the lower left quarter, and the late start date is in the lower right quarter. The difference between these two limits gives the float or slack for the activity/activities preceding the event.

Event 1 in the diagram represents the start of the project, and event 24 represents completion of the project. Various activities occur between these two events in a definite sequence. The network explains the relationship between various activities for the project.

An activity begins and ends with an event. Activities are represented by solid arrows joining the events, with the arrowhead at the ending event. The description of an activity is written above the arrow, and the estimate of time for an activity is indicated below the arrow. The dotted arrow or dummy represents an interrelationship but requires no time; dummies are introduced to indicate the technological relationship of the activities.

The heavier line formed by activities joining events 1 and 24 through events 2, 3, 4, 9, 10, 14, 22, and 23, is the critical path; any change in the time required for an activity on this path will affect the project duration by the same amount. Activities on the critical path have no slack.

The size of a network for a given project may vary according to requirements of different organizational levels. Senior management may use a macro network consisting of major representative activities. Department heads or project managers may require an intermediate network incorporating more details than those presented in the macro network. Project personnel (the on-site staff) will use a detailed micro network with activities exploded for execution of the project on site.

Figures 2-20 through 2-22 exemplify critical path networks for installation of a baghouse, limestone SO_2 scrubber system, and electrostatic precipitators. These schedules illustrate the complexity of the projects and the time increments involved in their completion.

2.3 CONTINGENCIES AFFECTING COMPLIANCE SCHEDULES

The compliance schedules compiled in this report represent "expeditious as practicable" control programs. These represent the minimum time required to achieve compliance, taking into account the lead times required for engineering design, equipment fabrication, field installation, and related activities. Successful completion of the projects in the indicated time periods requires minimizing the normal time variation in each of the component activities and avoiding major delays caused by unforeseen contingencies.

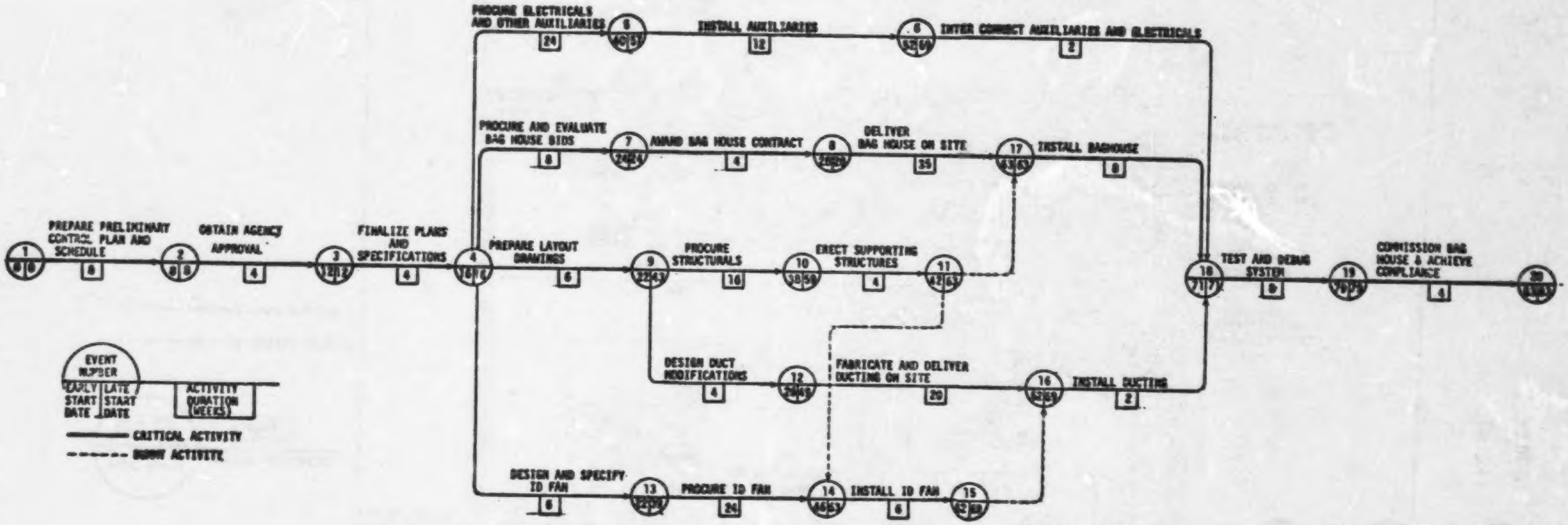

PREPARE PRELIMINARY CONTROL PLAN AND SCHEDULE
8
OBTAIN AGENCY APPROVAL
4
FINALIZE PLANS AND SPECIFICATIONS
4
PROCURE ELECTRICALS AND OTHER AUXILIARIES
24
INSTALL AUXILIARIES
12
INTER CONNECT AUXILIARIES AND ELECTRICALS
2
PROCURE AND EVALUATE BAG HOUSE BIDS
8
AWARD BAG HOUSE CONTRACT
4
DELIVER BAG HOUSE ON SITE
35
INSTALL BAGHOUSE
8
PREPARE LAYOUT DRAWINGS
6
PROCURE STRUCTURALS
16
ERECT SUPPORTING STRUCTURES
4
DESIGN DUCT MODIFICATIONS
4
FABRICATE AND DELIVER DUCTING ON SITE
20
INSTALL DUCTING
2
DESIGN AND SPECIFY ID FAN
6
PROCURE ID FAN
24
INSTALL ID FAN
6
TEST AND DEBUG SYSTEM
8
COMMISSION BAG HOUSE & ACHIEVE COMPLIANCE
4
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
EVENT NUMBER
EARLY START DATE
LATE START DATE
ACTIVITY DURATION (WEEKS)
CRITICAL ACTIVITY
DUMMY ACTIVITY

Figure 2-20. Critical path schedule for baghouse installation.

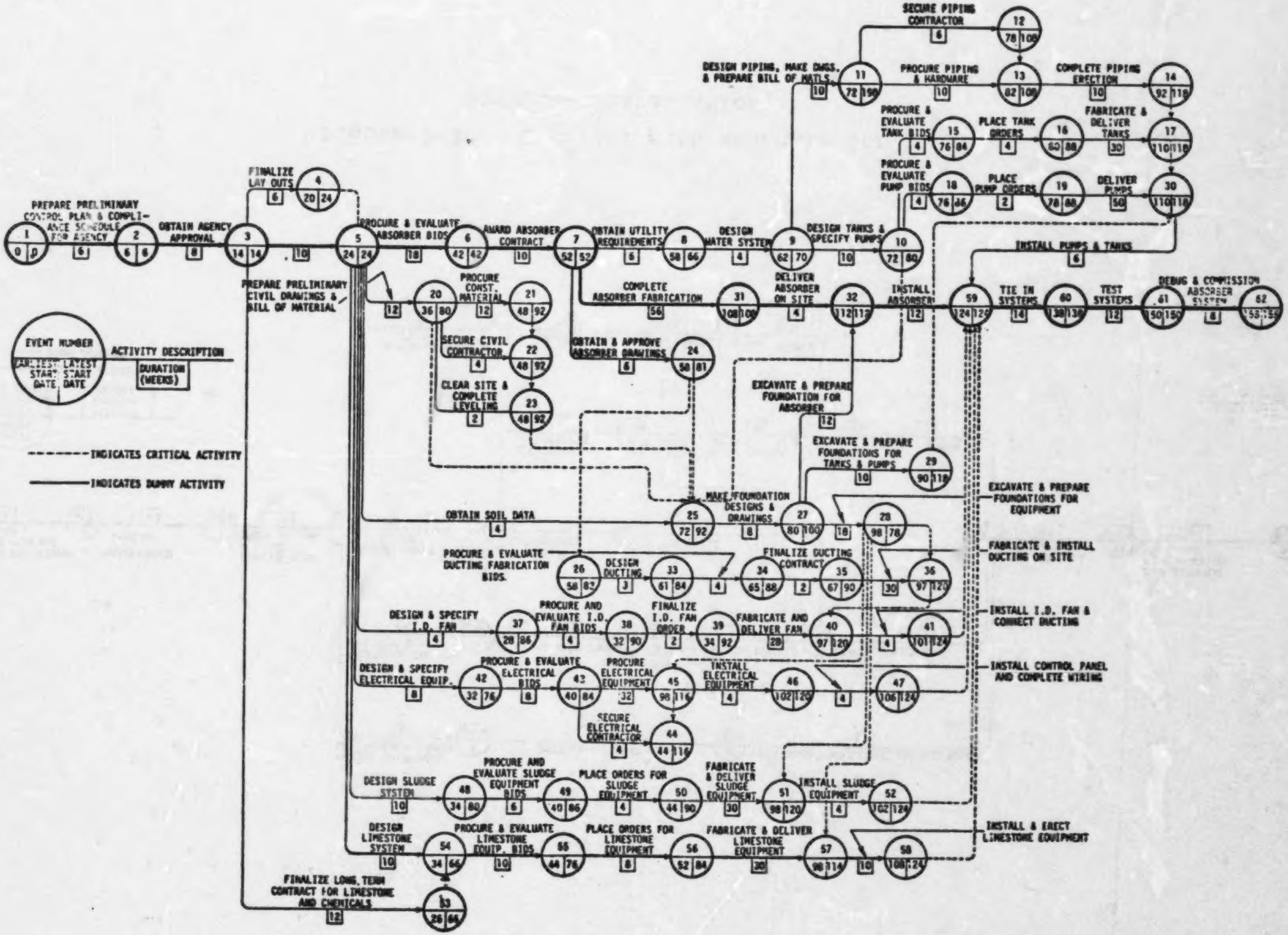

PREPARE PRELIMINARY CONTROL PLAN & COMPLIANCE SCHEDULE FOR AGENCY
OBTAIN AGENCY APPROVAL
FINALIZE LAY OUTS
PROCURE & EVALUATE ABSORBER BIDS
AWARD ABSORBER CONTRACT
OBTAIN UTILITY REQUIREMENTS
DESIGN WATER SYSTEM
DESIGN TANKS & SPECIFY PUMPS
DESIGN PIPING, MAKE DWGS. & PREPARE BILL OF MATLS.
SECURE PIPING CONTRACTOR
PROCURE PIPING & HARDWARE
COMPLETE PIPING ERECTION
PROCURE & EVALUATE TANK BIDS
PLACE TANK ORDERS
FABRICATE & DELIVER TANKS
PROCURE & EVALUATE PUMP BIDS
PLACE PUMP ORDERS
DELIVER PUMPS
INSTALL PUMPS & TANKS
PREPARE PRELIMINARY CIVIL DRAWINGS & BILL OF MATERIAL
PROCURE CONST. MATERIAL
SECURE CIVIL CONTRACTOR
CLEAR SITE & COMPLETE LEVELING
COMPLETE ABSORBER FABRICATION
OBTAIN & APPROVE ABSORBER DRAWINGS
DELIVER ABSORBER ON SITE
INSTALL ABSORBER
TIE IN SYSTEMS
TEST SYSTEMS
DEBUG & COMMISSION ABSORBER SYSTEM
EXCAVATE & PREPARE FOUNDATION FOR ABSORBER
EXCAVATE & PREPARE FOUNDATIONS FOR TANKS & PUMPS
OBTAIN SOIL DATA
MAKE FOUNDATION DESIGNS & DRAWINGS
EXCAVATE & PREPARE FOUNDATIONS FOR EQUIPMENT
PROCURE & EVALUATE DUCTING FABRICATION BIDS.
DESIGN DUCTING
FINALIZE DUCTING CONTRACT
FABRICATE & INSTALL DUCTING ON SITE
DESIGN & SPECIFY I.D. FAN
PROCURE AND EVALUATE I.D. FAN BIDS
FINALIZE I.D. FAN ORDER
FABRICATE AND DELIVER FAN
INSTALL I.D. FAN & CONNECT DUCTING
DESIGN & SPECIFY ELECTRICAL EQUIP.
PROCURE & EVALUATE ELECTRICAL BIDS
PROCURE ELECTRICAL EQUIPMENT
SECURE ELECTRICAL CONTRACTOR
INSTALL ELECTRICAL EQUIPMENT
INSTALL CONTROL PANEL AND COMPLETE WIRING
DESIGN SLUDGE SYSTEM
PROCURE AND EVALUATE SLUDGE EQUIPMENT BIDS
PLACE ORDERS FOR SLUDGE EQUIPMENT
FABRICATE & DELIVER SLUDGE EQUIPMENT
INSTALL SLUDGE EQUIPMENT
DESIGN LIMESTONE SYSTEM
PROCURE & EVALUATE LIMESTONE EQUIP. BIDS
PLACE ORDERS FOR LIMESTONE EQUIPMENT
FABRICATE & DELIVER LIMESTONE EQUIPMENT
INSTALL & ERECT LIMESTONE EQUIPMENT
FINALIZE LONG TERM CONTRACT FOR LIMESTONE AND CHEMICALS
EVENT NUMBER
EARLIEST START DATE
LATEST START DATE
ACTIVITY DESCRIPTION
DURATION (WEEKS)
INDICATES CRITICAL ACTIVITY
INDICATES DUMMY ACTIVITY

Figure 2-21. Critical path schedule for a limestone scrubbing system.

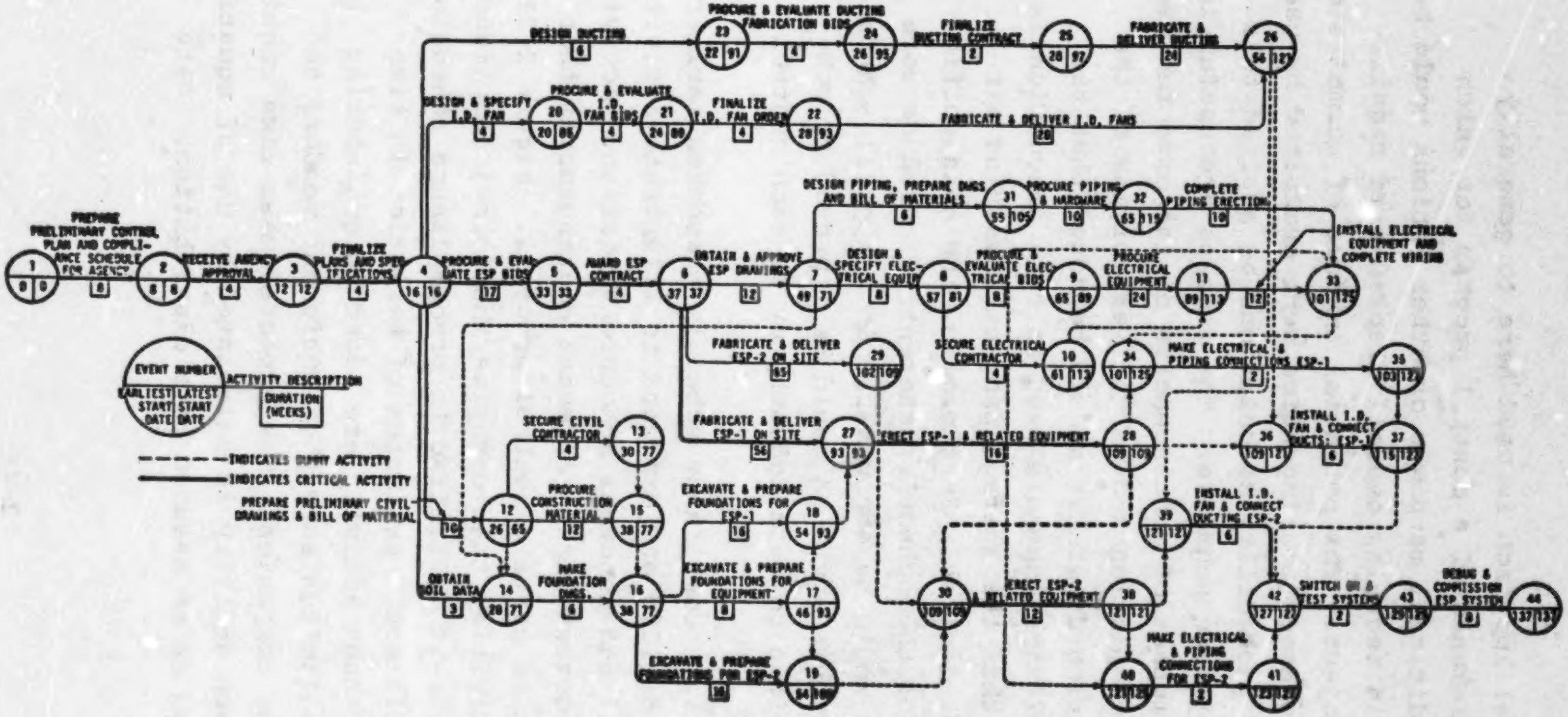
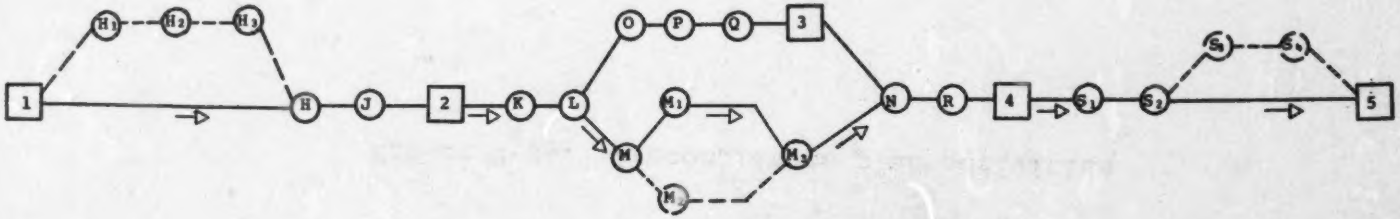

PREPARE PRELIMINARY CONTROL PLAN AND COMPLIANCE SCHEDULE FOR AGENCY
8
RECEIVE AGENCY APPROVAL
4
FINALIZE PLANS AND SPECIFICATIONS
4
PROCURE & EVALUATE ESP BIDS
17
AWARD ESP CONTRACT
4
OBTAIN & APPROVE ESP DRAWINGS
12
DESIGN & SPECIFY ELECTRICAL EQUIP
8
PROCURE & EVALUATE ELECTRICAL BIDS
8
PROCURE ELECTRICAL EQUIPMENT
24
12
INSTALL ELECTRICAL EQUIPMENT AND COMPLETE WIRING
DESIGN DUCTING
6
PROCURE & EVALUATE DUCTING FABRICATION BIDS
4
FINALIZE DUCTING CONTRACT
2
FABRICATE & DELIVER DUCTING
28
DESIGN & SPECIFY I.D. FAN
4
PROCURE & EVALUATE I.D. FAN BIDS
4
FINALIZE I.D. FAN ORDER
4
FABRICATE & DELIVER I.D. FANS
28
DESIGN PIPING, PREPARE DWGS AND BILL OF MATERIALS
6
PROCURE PIPING & HARDWARE
10
COMPLETE PIPING ERECTION
10
FABRICATE & DELIVER ESP-2 ON SITE
65
FABRICATE & DELIVER ESP-1 ON SITE
56
SECURE ELECTRICAL CONTRACTOR
4
MAKE ELECTRICAL & PIPING CONNECTIONS ESP-1
2
ERECT ESP-1 & RELATED EQUIPMENT
16
INSTALL I.D. FAN & CONNECT DUCTS: ESP-1
6
INSTALL I.D. FAN & CONNECT DUCTING ESP-2
6
ERECT ESP-2 & RELATED EQUIPMENT
12
MAKE ELECTRICAL & PIPING CONNECTIONS FOR ESP-2
2
SWITCH ON & TEST SYSTEMS
2
DEBUG & COMMISSION ESP SYSTEM
8
SECURE CIVIL CONTRACTOR
4
PROCURE CONSTRUCTION MATERIAL
12
PREPARE PRELIMINARY CIVIL DRAWINGS & BILL OF MATERIAL
10
OBTAIN SOIL DATA
3
MAKE FOUNDATION DWGS.
6
EXCAVATE & PREPARE FOUNDATIONS FOR ESP-1
16
EXCAVATE & PREPARE FOUNDATIONS FOR EQUIPMENT
8
EXCAVATE & PREPARE FOUNDATIONS FOR ESP-2
18
1 0 0
2 8 8
3 12 12
4 16 16
5 33 33
6 37 37
7 49 71
8 57 81
9 65 89
10 61 113
11 89 113
12 26 65
13 30 77
14 20 71
15 38 77
16 38 77
17 46 93
18 54 93
19 54 100
20 20 86
21 24 89
22 28 93
23 22 91
24 26 95
25 28 97
26 56 121
27 93 93
28 109 109
29 102 109
30 109 109
31 55 105
32 65 115
33 101 125
34 101 125
35 103 127
36 109 121
37 115 127
38 121 121
39 121 121
40 121 125
41 123 127
42 127 127
43 129 129
44 137 137
EVENT NUMBER
EARLIEST START DATE
LATEST START DATE
ACTIVITY DESCRIPTION
DURATION (WEEKS)
INDICATES DUMMY ACTIVITY
INDICATES CRITICAL ACTIVITY

Figure 2-22. Critical path schedule for installation of two electrostatic precipitators.

A statistical approach is used here to generally identify those elements of a control program for which assignment of additional manpower or other actions would be most beneficial in reducing overall elapsed-time requirements for the project. The potential impacts of normal time variance and unforeseen contingencies were evaluated by use of standard PERT probability calculations as applied to a generalized compliance schedule. The results are useful in determining the impact of contingencies on the expected mean time of project completion and on the variability of the predicted completion date. It should be noted that the generalized compliance schedule used in this discussion is somewhat longer than the average project involving air pollution control devices. Furthermore, the nonspecific characteristics of the schedule inherently introduce more variability than would be encountered in a typical schedule. The precision of this approach could be improved by compiling data specific to each industry or to each control device.

The generalized compliance schedule presented earlier in Section 2 is divided and expanded to illustrate activities subject to normal and abnormal schedule variation. Activities denoted by dotted lines represent contingencies that may be important in certain control programs. Figure 2-23 includes all activities that comprise the formal compliance schedule; Figure 2-24 is limited to precompliance schedule review and negotiation. Estimates of variation in time requirements for each activity are based on engineering experience and a limited survey of equipment vendors and other engineering companies. The expected mean time requirement (t_e) for each activity is calculated by use of equation 1, which is based on an assumed beta distribution. Beta



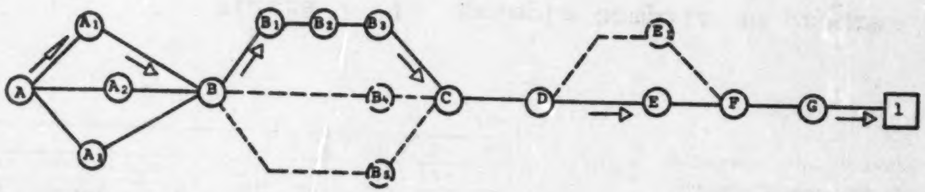
Activity	Action Taken	t_e	σ^2	t_{min}	t_p	t_{max}
$1-H_1$	Contact Vendors	2.17	0.56	1	2	4
H_1-H_2	Prepare Specifications	4.5	1.56	3	4	8
H_2-H_3	Procure Subcontractor Bids	3.83	5.06	1	3	10
H_3-H	Submit Formal Bids	2.17	0.56	1	2	4
I-H	No Revisions Necessary	0	0	0	0	0
H-J	Evaluate Bids	5.17	5.06	3	4	12
J-2	Award Contract	2.17	0.56	1	2	4
2-K	Vendor Assembly Drawings	6.67	4.0	4	6	12
K-L	Client Approval	4.33	2.25	2	4	8
L-O	Client Prepares Ste. Drawings	15.0	56.2	6	12	36
O-P	Procure Construction Bids	2.17	0.56	1	2	4
P-Q	Evaluate Bids	2.17	0.56	1	2	4
Q-3	Award Contract	2.17	0.56	1	2	4
3-N	Site Preparation	6.5	18.1	3	4	20
L-M	Vendor Fabrication Drawings	12.7	9.0	8	12	20
$M-M_1$	Vendor Acquires Std. Equipmt.	2.17	1.56	0	2	5
$M-M_2$	Vendors Acquires Spec. Matrls	23.2	100	10	20	50
M_1-M_3	Dummy	0	0	0	0	0

Activity	Action Taken	t_e	σ^2	t_{min}	t_p	t_{max}
M_2-M_3	Dummy	0	0	0	0	0
M_3-N	Fabricate Control Device	17.7	132	6	12	52
N-R	Field Installation	36.7	600	6	26	104
R-4	Tie-in	4.3	2.25	2	4	8
$4-S_1$	Start-up	9.0	20.2	2	8	20
S_1-S_2	Acceptance Test	4.3	2.25	2	4	8
S_2-5	Certify Compliance	4.3	2.25	2	4	8
S_2-S_3	Adjust and Modify	20.7	121	8	16	52
S_3-S_4	Retest	4.3	2.25	2	4	8
S_4-5	Certify Compliance	4.3	2.25	2	4	8

NOTE: Dotted lines indicate possible contingencies in schedule, arrows indicate "normal" critical path.

t_e = expected mean time, weeks
t_p = most probable time, weeks
t_{min} = minimum completion time, weeks
t_{max} = maximum completion time, weeks
σ^2 = completion time variance

Figure 2-23. Example compliance program.



Activity	Action Taken	t_e	σ^2	t_{min}	t_p	t_{max}
$A-A_1$	Source Test Preparation	4.7	4.0	2	4	10
A_1-B	Perform Test & Submit Report	4.3	2.2	2	4	8
$A-A_2$	Obtain Consultant	2.2	0.6	1	2	4
A_2-B	Consultant Evaluation	6.0	4.0	2	6	10
$A-A_3$	Obtain Chemical/Physical Data	2.2	0.6	1	2	4
A_3-B	Evaluate Operating Conditions	2.2	0.6	1	2	4
$B-B_1$	Contact Equipment Vendors	2.2	0.6	1	2	4
B_1-B_2	Prepare Control Device Specs	4.5	1.6	3	4	8
B_2-B_3	Procure Subcontractor Bids	5.1	3.8	1	3	10
B_3-C	Vendors Submit Bids	2.2	0.6	1	2	4
$B-B_4$	Evaluate Fuel/Feedstk Changes	30.3	600	2	20	100
$B-B_5$	Evaluate Proc. Design Changes	30.3	600	2	20	100
B_4-C	Dummy	0	0	0	0	0
B_5-C	Dummy	0	0	0	0	0
C-D	Evaluate Control Alternatives	5.2	5.1	3	4	12

Activity	Action Taken	t_e	σ^2	t_{min}	t_p	t_{max}
$D-E_1$	Legal Negotiations	18	156	2	8	52
E_1-F	Dummy	0	0	0	0	0
D-E	Reserve Funds	0.7	4.0	2	4	10
E-F	Prepare Preliminary Plan	2.2	0.6	1	2	4
F-G	Agency Approval and Review	6.3	6.2	2	6	12
G-1	Finalize Control Plans	4.3	2.2	2	4	8

NOTE: Dotted lines indicate possible contingencies in schedule, arrows indicate "normal" critical path.

t_e = expected mean time, weeks

t_p = most probable time, weeks

t_{min} = minimum completion time, weeks

t_{max} = maximum completion time, weeks

σ^2 = completion time variance

Figure 2-24. Precompliance plan activities

distribution is biased toward longer time periods and has been useful in a variety of engineering and construction projects.

$$t_e = \frac{t_{min} + (4 \times t_{most\ probable}) + t_{max}}{6} \qquad \text{Equation 1}$$

$$\sigma^2 = \frac{t_{max} - t_{min}}{4} \qquad \text{Equation 2}$$

where

t_e = expected mean time, weeks (completion time with a probability of 50 percent),

t_{min} = minimum time, weeks,

t_{max} = maximum time, weeks,

$t_{most\ probable}$ = time of greatest statistical probability (peak of beta distribution),

σ^2 = variance of completion time.

Variance is calculated according to equation 2. Because of the limited sample population, a denominator of 4 is used instead of the more common value of 6. The overall completion time estimates for the project are calculated by summation of the elements along the critical path. The resulting completion probabilities for a "normal" project are indicated in the first columns of Tables 2-4 and 2-5 for the compliance program and preschedule activities, respectively.

2.3.1 Normal Variation in Time Requirements

Inspection of the data included in Figure 2-23 indicates that half of the total time requirement and most of the variance is introduced in the fabrication (M_3 to N) and field installation (N to R) activities (see elements along critical path). Following are some of the factors that contribute to normal variation.

Table 2-4. EFFECT OF CONTINGENCIES ON COMPLIANCE PLAN ACTIVITIES

Probability of completion in time specified, %	Time required for project completion, weeks[a]			
	Normal	Revised bids	Special materials and/or equipment	Noncompliance
95	160	168	180	190
90	147	158	171	180
80	133	147	159	166
70	124	136	150	156
60	116	129	141	147
50	109	122	133	139
40	103	115	126	132
30	95	107	118	123

[a] The time estimates are illustrative only; they do not necessarily apply to a specific type of control device or a specific industry.

Table 2-5. EFFECT OF CONTINGENCIES ON PRECOMPLIANCE PLAN ACTIVITIES

Probability of completion in time specified, %	Time required for plan development, weeks		
	Normal	Process research	Legal negotiations
90	52	74	100
80	49	66	87
70	47	61	77
60	45	56	70
50	44	51	62
40	43	47	47

Type of Control Device

The complexity of the common air pollution control devices varies substantially. Fabrication of electrostatic precipitators, for example, requires more time than fabrication of mechanical collectors or fabric filters. The data presented in this report indicate that complexity of the control device is responsible for 25 to 50 percent of the total variation.

Scale of Installation

Field erection time and, to some extent, fabrication time are proportional to the scale of the control facility. Installation of multiple units requires considerable site preparation, duct construction, electrical connection, and related work. Space requirements can also impede expeditious installation.

Retrofit Difficulty

Installation of large air pollution control devices at existing facilities can require substantially greater time periods than incorporation of similar controls into new facilities. Site preparation could be more difficult because of underground tanks, overhead power lines, or existing structures. Restricted access can dictate the type of equipment used to erect the support structure and to install the control device.

Availability of Skilled Labor

Backlogs can affect both fabrication and field erection. The susceptibility of projects to availability of skilled labor is roughly proportional to the complexity of the control device and the scale of the installation. Geographical distribution of skilled personnel must sometimes be considered. Strikes can result in substantial delays.

Other normal factors that influence the length of time required to achieve compliance include availability of engineering and drafting personnel (activities 2-k, L-M, and L-O), difficulty of start-up (activity 4-S_1), and acceptance testing (activity S_1-S_2). Tie-in of the control device to an already operating process can require lengthy periods if temporary shutdown of the process would result in severe economic loss. In such cases, it is conceivable that tie-in would be delayed until a scheduled process maintenance period. Tie-in time can be minimized by installing blinded tie-in flanges and ductwork during the construction phase. If normal weather patterns are considered, severe weather should not be a major delaying factor. Obviously, scheduling of construction during midwinter in northern areas should be avoided, and the site should be protected from water accumulations.

The variation in time requirements shown in Table 2-4 accounts for these contingency factors. The estimated variation data show a 95 percent probability that all of the project will be completed in 160 weeks and a 30 percent probability of completion within 95 weeks. The expected mean time (50 percent probability) is 109 weeks, barring such unusual factors as revised bids, special material, or extra shakedown time. The precision of the estimates could be improved by factoring in the type of control device and the difficulty of field erection.

In projects subject to normal variation only, the fabrication and field erection activities require greatest attention to minimize time requirements. Time requirements can be reduced by ensuring the availability of adequate skilled labor, by reducing tie-in delays, and by minimizing effects of adverse weather.

2.3.2 Contingencies in Project Time Requirements

A number of contingencies can substantially delay compliance work. The impact of these factors on the probability of completion has also been estimated by use of PERT calculation procedures.

Special Materials and Accessories

Certain installations require special materials of construction to withstand severe conditions. Delays in receipt of stainless steels or nickel alloy steels are not unusual. Figure 2-23 indicates that this factor has a direct impact on the critical path (see activity $M-M_2$). Acquisition of special components such as fans, pumps, and electrical parts may involve similar delays; these are usually less severe, however, since fabrication can generally proceed without these components. As shown in column 2 of Table 2-4, this problem could increase the expected mean time from 109 to 133 weeks and could increase the variability slightly. Except for avoiding any unnecessary use of special materials or hard-to-get accessories, very little can usually be done to compress the time requirement for such contingencies.

Revised Bids

Depending on the elapsed time involved in compliance plan development, it is occasionally necessary to obtain updated bids from equipment vendors. Such bids are generally valid for only 60 or 90 days. As indicated in the dotted line $1-H_1-H_2-H_3-H$ on Figure 2-23, this process adds approximately 12 weeks to the project time requirement. It causes only a minor shift in the completion probability estimates. Since haste in the design stage can cause major problems at a later stage, compression of the schedule for this activity is seldom prudent.

Noncompliance

In certain cases it is impossible to achieve performance guarantees and compliance through normal adjustment of the control device. Evaluation of the operational problems can include airflow studies in models, extensive on-site inspection, and redetermination of pollutant characteristics (particle size, particle composition, resistivity, pollutant concentration, gas flow variation, etc.). Minor modifications of the control equipment require most of the time listed in activity S_2 to S_3. Adjustment and modification work increases the expected mean time from 109 tc 139 weeks. This factor exerts the greatest impact of any factor identified and obviously deserves careful attention. In view of the extensive potential time delay and costs, the activities of equipment selection, design, and installation should not be accelerated unnecessarily.

Development of Final Compliance Plan

The work discussed thus far involves the actual design, fabrication, and installation of equipment. Obviously none of this work can be initiated until a formal plan has been developed by the owner and approved by regulatory authorities. Several factors can delay the plan development. A control device is generally selected only after the owner has determined that changes in process design or feedstock/fuel are not economical or technically feasible. Evaluation of the control alternatives can require a lengthy period, depending primarily on the complexity of the process. As shown in Table 2-5, these preliminary studies can shift the expected mean time for generating a final plan from 44 weeks to 51 weeks and can substantially increase the variability.

After completing a preliminary review of the control alternatives and costs, the owner may choose to challenge the need for control or the extent of control required. Such a challenge could result in substantial delays, depending on the legal action involved. The potential delay is roughly estimated as 18 weeks.

On the basis of the completion probability data in Table 2-4, it is estimated that delays in developing a formal compliance schedule could delay achievement of compliance by 6 to 12 months.

2.3.3 Conclusions

The completion probability estimates suggest several activities that can facilitate expeditious compliance. Development of the formal compliance plan should be done in the minimum of time that allows adequate evaluation of control alternatives. The regulatory requirements should be stated clearly to prevent or minimize the use of time in legal negotiations. Emphasis should be placed on acquisition of representative data on pollutant loads and characteristics to avert noncompliance problems. Time requirements for procuring special materials of construction should be incorporated into schedules to provide realistic compliance dates.

3.0 COMPLIANCE SCHEDULES FOR SELECTED INDUSTRIAL SOURCES

3.1 STATIONARY COMBUSTION

3.1.1 Coal-Fired Utility Boilers

Process Description - Individual coal-fired utility boilers range in size from small units generating about 20 MW of power to units generating over 1000 MW. The smaller units are usually operated for peak loading (i.e. to generate the additional power needed during peak power usage hours), whereas the larger boilers are usually operated continously to provide the base load. At large power generating stations with several boilers, generating capacities can reach several thousand megawatts.

The overall process for power generation at a coal-fired utility is shown schematically in Figure 3-1. Coal is usually received by barge or rail, sized, and then fired into the furnace; the heat from combustion is used to produce steam for generating power. Most coal-fired utilities use either pulverized coal or cyclone-fired boilers, the pulverized-coal-fired units vastly predominating. Almost all units in current use are equipped with some type of device for fly ash control.

Atmospheric Emissions - Sources of particulate emission include the coal receiving and handling operations, the furnace flue gases, and the ash disposal operations. Of these, the fly ash contained in the flue gases represents the largest particulate emission source. The flue gases also can contain substantial amounts of sulfur oxides and nitrogen oxides.

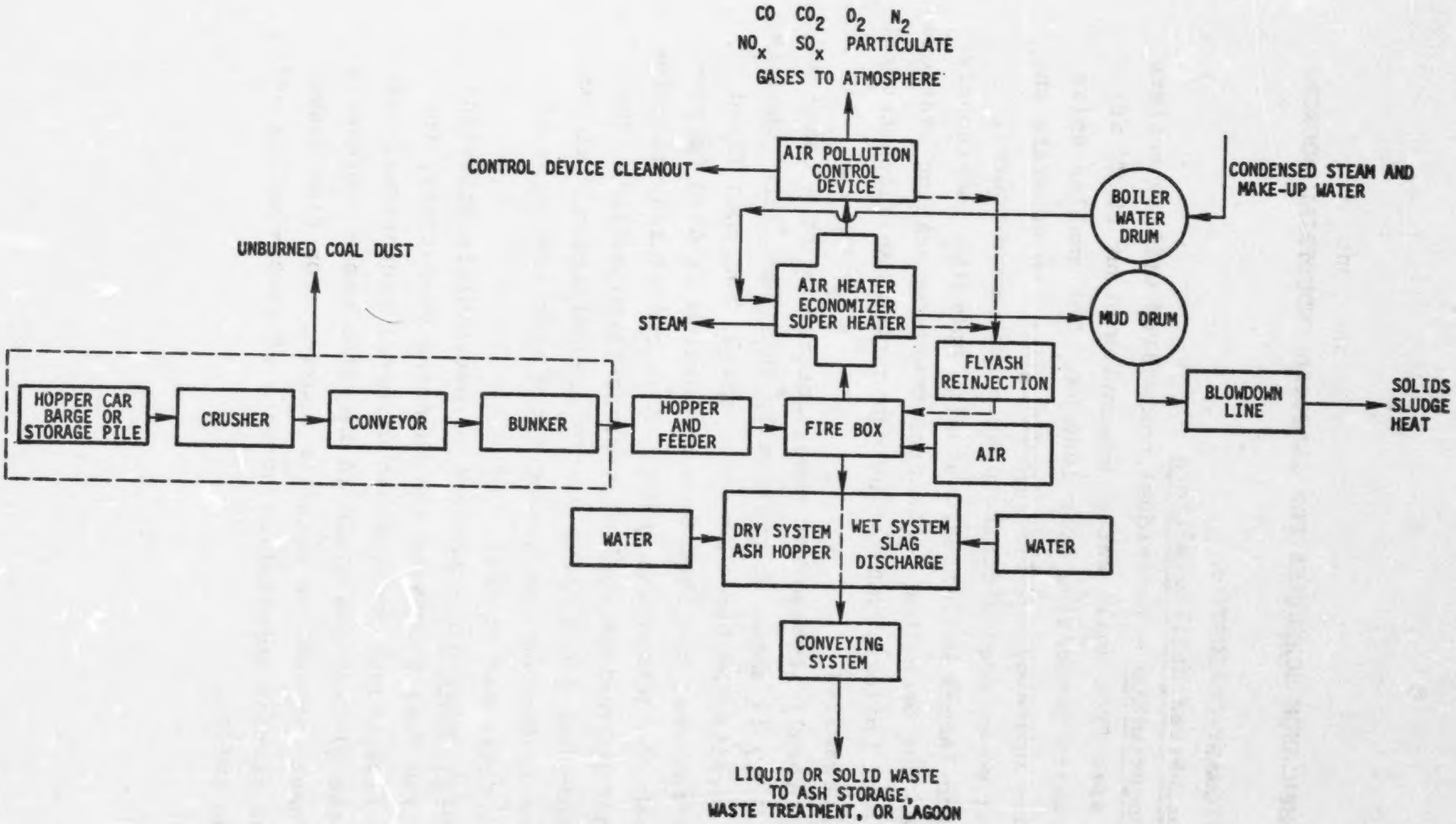

CO CO_2 O_2 N_2
NO_x SO_x PARTICULATE
GASES TO ATMOSPHERE
AIR POLLUTION CONTROL DEVICE
CONTROL DEVICE CLEANOUT
CONDENSED STEAM AND MAKE-UP WATER
BOILER WATER DRUM
UNBURNED COAL DUST
AIR HEATER ECONOMIZER SUPER HEATER
STEAM
MUD DRUM
FLYASH REINJECTION
BLOWDOWN LINE
SOLIDS SLUDGE HEAT
HOPPER CAR BARGE OR STORAGE PILE
CRUSHER
CONVEYOR
BUNKER
HOPPER AND FEEDER
FIRE BOX
AIR
WATER
DRY SYSTEM ASH HOPPER
WET SYSTEM SLAG DISCHARGE
WATER
CONVEYING SYSTEM
LIQUID OR SOLID WASTE TO ASH STORAGE, WASTE TREATMENT, OR LAGOON

Figure 3-1. Steam generation at a coal-fired utility.

Pulverized-coal-fired boilers generally emit, as fly ash, between 75 and 85 percent of the ash content of the coal. For example, a unit burning coal having 10 percent ash content emits approximately 160 pounds of fly ash per ton of coal burned. Cyclone-fired units emit considerably less, approximately 10 percent of the total ash content of the coal; a unit burning coal having 10 percent ash content emits approximately 20 pounds fly ash per ton of coal burned.

Nationwide, particulate emissions from coal-fired boilers may increase during the next few years. Two factors, available fuels and controls, will contribute to this emission increase. The limited availability of oil and gas fuels will result in the conversion back to coal-firing of some oil- and gas-fired boilers that formerly burned coal. Oil- or gas-fired boilers that have never burned coal cannot be converted to coal firing without equipment modification or capacity reduction because of physical size and general design. To comply with SO_2 regulations some utilities may switch from high-sulfur to low-sulfur coal. The change in resistivity of the fly ash can decrease the efficiency of an electrostatic precipitator for particulate control. The addition of precipitator sections can prevent an increase in particulate emissions.

Control Systems - Electrostatic precipitators have been used almost exclusively for high-efficiency particulate control. These devices are capable of operating with collection efficiencies of more than 99 percent. In design of the precipitator, particular attention must be paid to the properties of the coal and the expected precipitator operating temperature; both parameters influence fly ash resistivity, which in turn directly affects collection efficiency.

Flue gas conditioning is sometimes used when fly ash resistivity prevents efficient particulate removal by existing precipitators. Conditioning involves injecting SO_3, ammonia, or other chemicals into the flue gas to improve fly ash resistivity and in turn increase the fly ash collection efficiency. The degree of improvement in collection efficiency depends on the resistivity of the dust before flue gas treatment and the operating condition of the precipitator. Increases in efficiency of up to 40 percent have been reported, but a 10 percent increase would be more typical.[7]

Fabric filters can also be used to control particulate emissions from coal-fired boilers. Although they have been used to only a very limited extent, their use may increase in the future because of their ability to control fine particulate emissions. Particulate collection efficiencies of over 99 percent can be expected. Fly ash resistivity has no effect on collection efficiency of fabric filters but flue gas temperatures must be high enough to prevent condensation on the fabric even at low loads.

Within the last few years, wet scrubbers have also been installed to control particulate emissions from coal-fired boilers. Usually such installations are made in anticipation of converting the scrubber system to collect both SO_2 and particulate.

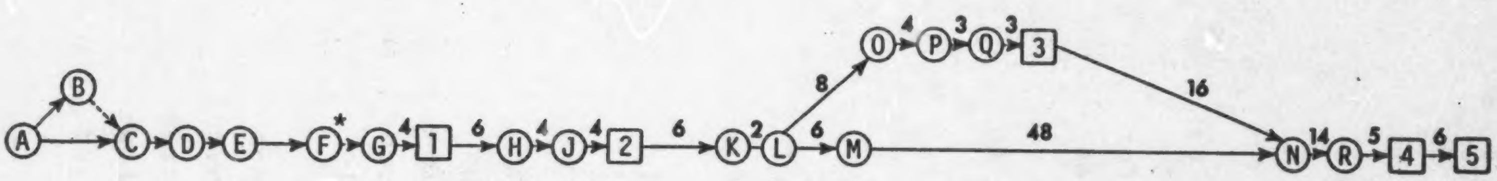
Some plants are using flue gas desulfurization (FGD) systems for control of SO_2. These SO_2 absorption systems are located downstream of the particulate collection device and typically remove about 85 percent of the SO_2 in the gas stream. The systems are classified as either nonregenerable or regenerable. Nonregenerable systems (for example the lime, limestone, and double-alkali systems) produce a nonusable sludge that must be disposed of by landfill, whereas regenerable systems (for example the Wellman-Lord and magnesium oxide systems) recover the collected SO_2, which is ultimately used to produce sulfur or sulfuric acid.

Conversion from coal to oil or gas as fuel also effectively reduces particulate and SO_2 emissions.

Compliance Schedules - Figures 3-2 through 3-4 illustrate expeditious schedules for installation of an electrostatic precipitator, fabric filter, and wet scrubber for particulate control. Schedules for installation of FGD systems for boilers larger and smaller than 500 MW are shown in Figures 3-5 and 3-6. Differences in the compliance schedules of regenerable and nonregenerable FGD systems are too slight to warrant separate schedules.

Figure 3-2 shows a typical compliance schedule for controlling a large utility boiler. With an ESP control device, fabrication requiring approximately 48 weeks constitutes the longest time increment, followed by a control device installation time of 14 weeks. Total compliance time is 105 weeks. As shown in Figure 3-3, the longest time increment required for compliance with a fabric filter is the 52 weeks necessary for control device fabrication, with a total time of 106 weeks. As shown in Figure 3-4, a scrubber can be installed on a coal-fired utility boiler in approximately 83 weeks. This interval is from the time an agency grants approval of compliance plans until completion of control device shakedown and the preliminary source test. The longest time increment is 20 weeks for control device fabrication.

FGD systems require water treatment facilities, sludge handling equipment, and (for a regenerable system) a chemical processing plant. Schedules for installation of FGD systems on a small and large (greater than 500 MW) boilers are shown in Figures 3-5 and 3-6, respectively. Total times required



* Refer to Chapter 2 for time increments A to G.

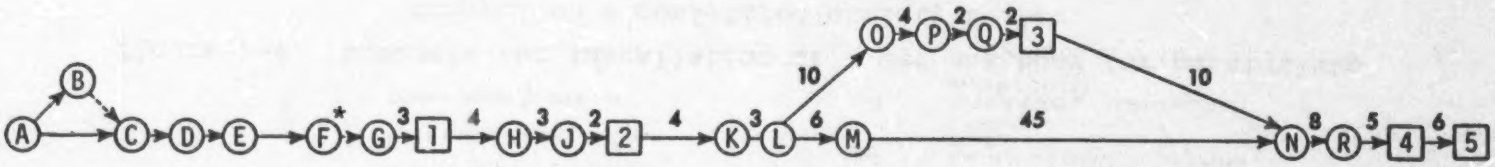
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	18
3	Date of initiation of on-site construction or installation of emission control equipment.	44
4	Date by which on-site construction or installation of emission control equipment is completed.	99
5	Date by which final compliance is achieved.	105

Activity designation	Activity description
A-B	Conduct source tests
A-C	Perform preliminary investigation
C-D	Evaluate control alternatives
D-E	Commit funds for total program
E-F	Prepare control plan and compliance schedule for agency
F-G	Agency reviews and approves plans
G-1	Finalize plans and specifications
1-H	Procure control device bids
H-J	Evaluate control device bids
J-2	Award control device contract
2-K	Prepare assembly drawings
K-L	Review and approve assembly drawings
L-M	Prepare fabrication drawings
M-N	Fabricate control device
L-O	Prepare engineering drawings
O-P	Procure construction bids
P-Q	Evaluate construction bids
Q-3	Award construction contract
3-N	Initiate on-site construction
N-R	Install control device
R-4	Complete construction and system tie-in
4-5	Perform startup, shakedown, and emission testing

Figure 3-2. Schedule for installation of an electrostatic precipitator on a 500-MW coal-fired boiler.



* Refer to Chapter 2 for time increments A to G.

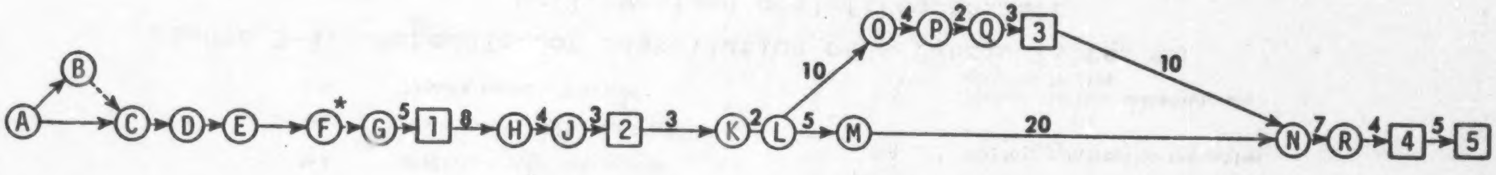
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	37
4	Date by which on-site construction or installation of emission control equipment is completed.	83
5	Date by which final compliance is achieved.	89

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-3. Schedule for installation of a fabric filter on utility-sized coal-fired boilers.



* Refer to Chapter 2 for time increments A to G.

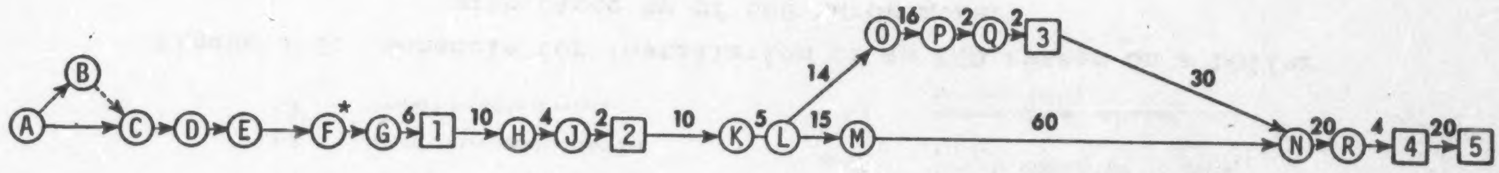
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	5
2	Date of award of control device contract.	20
3	Date of initiation of on-site construction or installation of emission control equipment.	44
4	Date by which on-site construction or installation of emission control equipment is completed.	65
5	Date by which final compliance is achieved.	70

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-4. Schedule for installation of a wet scrubber for particulate control on a coal-fired utility boiler.



* Refer to Chapter 2 for time increments A to G.

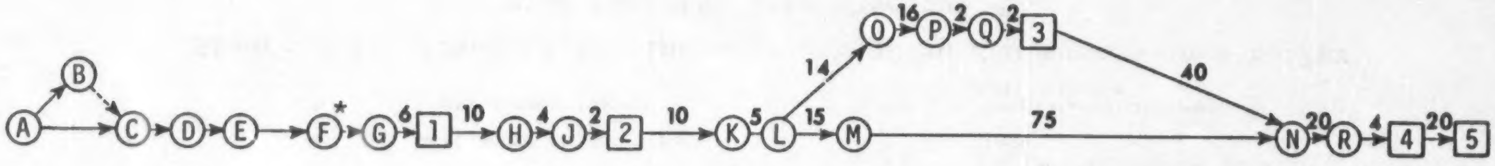
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	22
3	Date of initiation of on-site construction or installation of emission control equipment.	71
4	Date by which on-site construction or installation of emission control equipment is completed.	136
5	Date by which final compliance is achieved.	156

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-5. Schedule for installation of an FGD system on a boiler with capacity less than 500 MW.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

——→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	22
3	Date of initiation of on-site construction or installation of emission control equipment.	71
4	Date by which on-site construction or installation of emission control equipment is completed.	151
5	Date by which final compliance is achieved.	171

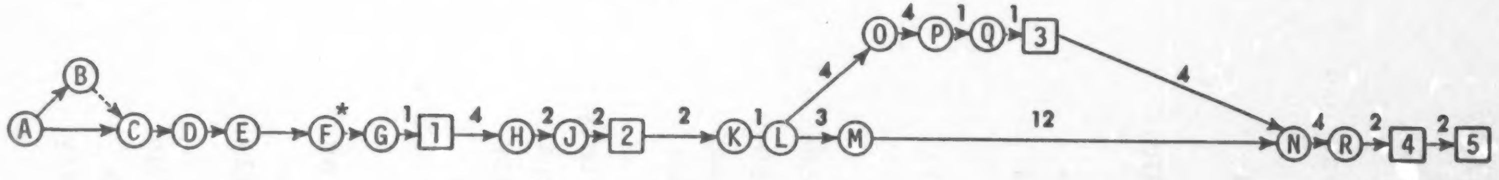
Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-6. Schedule for installation of an FGD system on a boiler with capacity of 500 MW or more.

for compliance by use of FGD are approximately 156 and 171 weeks for coal-fired boilers of capacities less than and greater than 500 MW respectively. The longest time increment is for control device fabrication, approximately 60 and 75 weeks for the small and large boilers, respectively. Regenerable and nonregenerable FGD systems require approximately the same installation time. Construction and installation of chemical process equipment and scrubber equipment can normally be done concurrently.

The elapsed time of these schedules may increase as a result of delays in control device fabrication, staggering the installation of several devices at one site, retrofit difficulty, and start-up problems. The time delay, if any, caused by backlogs of orders or delivery scheduling can be estimated by the manufacturer. Approximately 12 to 24 weeks is usually required for installation of each additional precipitator after the first unit has been completed, because utilities must stagger the down times of the various boilers to meet power generation requirements. Although this additional time can be shortened, the schedules must be considered on an individual basis for each utility. The variety of start-up problems encountered with large control devices can entail more than 6 months delay unless both the utility and control system manufacturers make an intensive effort to rectify the difficulties promptly.

Installation time of a flue gas conditioning system ranges from approximately 6 weeks to 8 months, depending on the chemical used to treat the gas, the equipment requirements, and the boiler configuration. Properties of the fly ash and plant economics will determine which flue gas conditioning system is best for each plant. An expeditious compliance schedule for a flue gas conditioning system is shown in Figure 3-7. Specialty chemical systems reportedly



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	1
2	Date of award of control device contract.	9
3	Date of initiation of on-site construction or installation of emission control equipment.	22
4	Date by which on-site construction or installation of emission control equipment is completed.	33
5	Date by which final compliance is achieved.	35

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-7. Compliance schedule for flue gas conditioning on a utility-size boiler.

require as little as 6 weeks for installation and shakedown, but operating costs may be much higher than those of other systems.

Sources of Additional Information

	Source	Type of information*
1.	Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Prepared by Midwest Research Institute for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 203 522. May 1971. 613 p.	P, E, C
2.	Oglesby, S. and G.B. Nichols. A Manual of Electrostatic Precipitator Technology. Part II - Application Areas. Prepared by Southern Research Institute for the National Air Pollution Control Administration, Cincinnati, Ohio. NTIS No. PB 196-381. August 1970. 875 p.	C
3.	Steam, Its Generation and Use. Babcock and Wilcox Co., New York, 1963.	P
4.	Smith, W.S. and C.W. Gruber. Atmospheric Emissions from Coal Combustion, An Inventory Guide. U.S. Public Service, Cincinnati, Ohio. Publication No. AP-24. April 1966. 114 p.	P, E
5.	Feazel, C.E., ed. Symposium on Electrostatic Precipitators for the Control of Fine Particles. Prepared by Southern Research Institute for the Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C. Publication No. EPA-650/2-75-016. January 1975. 489 p.	P, E, C

6.	Proceedings: Symposium on Flue Gas Desulfurization - Atlanta, November 1974, Volume II. U.S. Environmental Protection Agency, Washington, D.C. Publication No. EPA-650/2-74-126b. December 1974. 531 p.	P, E, C
7.	Green, G.P. and W.S. Landers. Operating Experience with Gas Conditioned Electrostatic Precipitators. Public Service Company of Colorado. January 1974. 5 p.	P, E, C
8.	Inspection Manual for the Enforcement of New Source Performance Standards: Fossil-Fuel-Fired Steam Generators. Prepared by PEDCo Environmental Specialists for the U.S. Environmental Protection Agency, Washington, D.C. Publication No. EPA 340/1-75-002. January 1975. 140 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.1.2. Coal-Fired Industrial Boilers

Process Description - Coal-fired industrial boilers are generally distinguished from large utility boilers by their size, coal-firing method, and operating steam pressure. Capacities of industrial boilers are lower, ranging from 1000 to 500,000 pounds per hour of steam. Pulverized-coal-fired boilers are used for generating steam loads of 300,000 pounds per hour or higher. The smaller boilers are often operated with wide variations in loads, and stoker-fired furnaces are uniquely suited to this fluctuating demand.

Atmospheric Emissions - Sources of atmospheric emissions from industrial boilers are identical to those from utility boilers: the coal receiving and handling operations, the furnace flue gases, and the ash disposal operations. Fly ash in the flue gas represents the major particulate emission source. The quantity emitted depends upon the ash content of the coal, the method of combustion, and the control equipment. Uncontrolled pulverized-coal-fired boilers burning coal with 10 percent ash generally emit about 160 pounds of fly ash for each ton of coal burned. Emissions from stoker-fired furnaces burning bituminous coal containing 10 percent ash are about 130 pounds per ton of coal, but these emissions vary widely.

Sulfur dioxide emissions from industrial boilers are also of concern. The quantity emitted depends upon the sulfur content of the coal.

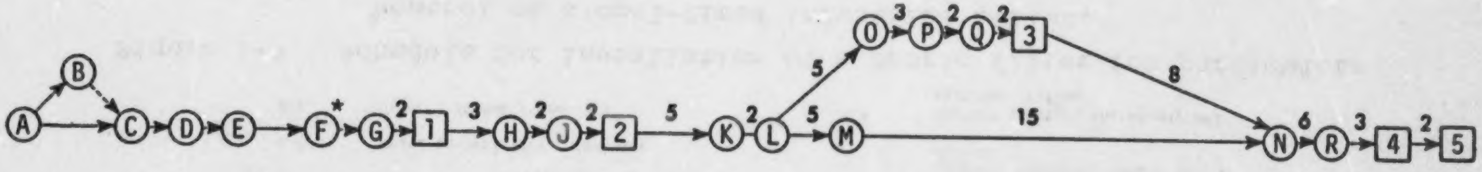
Control Systems - Electrostatic precipitators have been used almost exclusively for high-efficiency particulate emission control. Their use on industrial size boilers has not been widespread, however; most controlled installations are equipped only with multiple cyclones. Electrostatic precipitators can attain efficiencies of more than 99 percent.

In precipitator design, particular attention should be given to the coal composition and the expected operating precipitator temperature, since both factors affect collection efficiency.

Multiple dry high-efficiency cyclones are also used to collect particulate emissions. Cyclones are also used as a precleaner to reduce the dust loading on a secondary control device, usually an electrostatic precipitator. High-efficiency cyclones typically collect 65 to 75 percent of the fly ash when applied to pulverized-coal-fired boilers.

Some facilities are installing wet scrubbers for fly ash control because of the possibility of modifying the control system at a later date for collection of sulfur oxides.

Compliance Schedules - Figures 3-8 through 3-11 illustrate expeditious schedules for installation of a multiple cyclone, a fabric filter, an electrostatic precipitator, and a wet scrubber for fly ash control. The time required for installation of additional units on the same site after completion of the first unit can add 3 months to the schedule. No schedule is shown for SO_2 and NO_x control, since these systems are not widely used on industrial boilers at this time.



* Refer to Chapter 2 for time increments A to G.

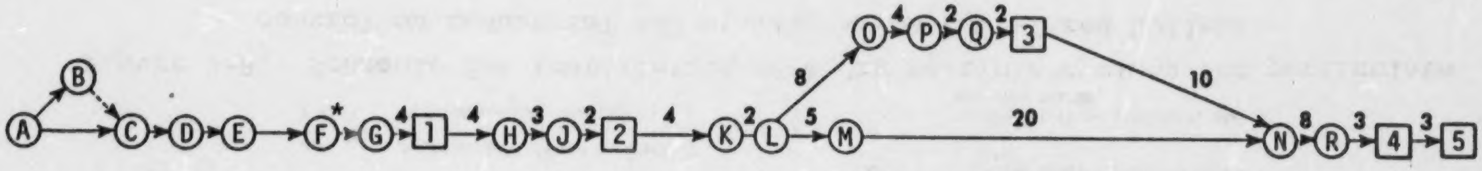
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	9
3	Date of initiation of on-site construction or installation of emission control equipment.	28
4	Date by which on-site construction or installation of emission control equipment is completed.	45
5	Date by which final compliance is achieved.	47

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-8. Schedule for installation of a dry multiple cyclone for particulate control on industrial and utility-sized coal-fired boilers.



* Refer to Chapter 2 for time increments A to G.

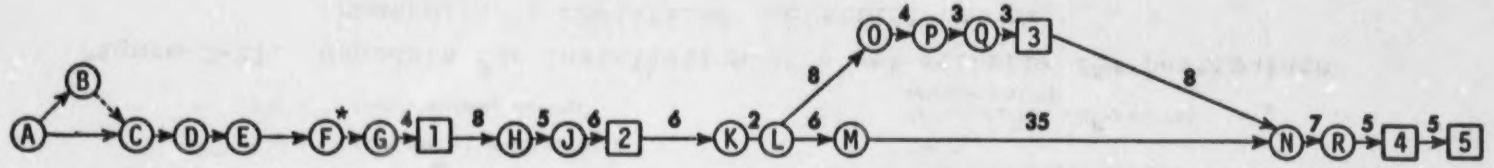
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	13
3	Date of initiation of on-site construction or installation of emission control equipment.	35
4	Date by which on-site construction or installation of emission control equipment is completed.	56
5	Date by which final compliance is achieved.	59

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-9. Schedule for installation of a fabric filter for particulate control on a coal-fired industrial boiler.



* Refer to Chapter 2 for time increments A to G.

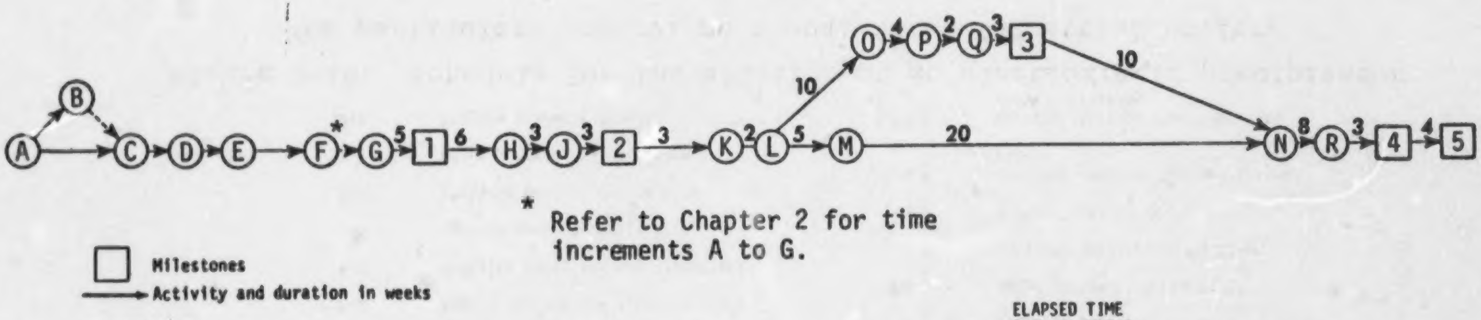
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	23
3	Date of initiation of on-site construction or installation of emission control equipment.	49
4	Date by which on-site construction or installation of emission control equipment is completed.	84
5	Date by which final compliance is achieved.	89

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-10. Schedule for installation of an electrostatic precipitator for particulate control on a coal-fired industrial boiler.



* Refer to Chapter 2 for time increments A to G.

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	5
2	Date of award of control device contract.	17
3	Date of initiation of on-site construction or installation of emission control equipment.	41
4	Date by which on-site construction or installation of emission control equipment is completed.	62
5	Date by which final compliance is achieved.	66

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-11. Schedule for installation of a wet scrubber for particulate control on a coal-fired industrial boiler.

Sources of Additional Information

	Source	Type of information*
1.	Oglesby, S. and G. B. Nichols. A Manual of Electrostatic Precipitator Technology. Part II - Application Areas. Prepared by Southern Research Institute for the National Air Pollution Control Administration, Cincinnati, Ohio. NTIS No. PB-196-381. August 1970. 875 p.	C
2.	Smith, W.S. and C.W. Gruber. Atmospheric Emissions from Coal Combustion, An Inventory Guide. U.S. Public Health Service. Cincinnati, Ohio. Publication No. AP-24. April 1966. 114 p.	P, E
3.	Steam, Its Generation and Use. Babcock and Wilcox Co., New York, 1963.	P
4.	Background Information for Proposed New-Source Performance Standards: Steam Generators, Incinerators, Portland Cement Plants, Nitric Acid Plant, and Sulfuric Acid Plants. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. PB 202-459. August 1971. 50 p.	E, C

*P = Process description
E = Emission rates
C = Control devices

3.2 WASTE DISPOSAL

3.2.1 Municipal Incinerators

Process Description - Capacities of municipal incinerators range from approximately 50 to 1000 tons of refuse per day. In the incineration process, as shown in Figure 3-12, refuse is brought to the unloading/charging area. It is then fed to the incinerator, either in batches or continuously, and the combustible fraction of the refuse is burned. In multiple-chamber units, air may be added in mixing or secondary chambers to complete the combustion of the volatile materials driven off in the primary refuse-burning chamber.

The ash residue from the furnace is periodically removed, quenched, and disposed of, usually in a landfill.

Atmospheric Emissions - Sources of particulate emissions include combustion gases from the furnace and fugitive dust emissions from the handling and disposing of ash from furnace and control device hoppers. Odors can also be a problem if proper housekeeping procedures are not strictly followed. Of these sources, the furnace combustion gases represent the largest emission potential. The particulate emission rate is highly variable, depending upon such factors as furnace design, operating conditions, and type and characteristics of the refuse. Particulate emissions from an uncontrolled incinerator typically range between 8 and 70 pounds per ton of refuse burned.

Control System - Many incinerators are designed with a settling chamber and water spray or baffle as an integral part of the incinerator system. Although these are considered air pollution control systems, their collection efficiencies are generally very low on a weight basis. They do not provide sufficient control to meet most emission regulations.

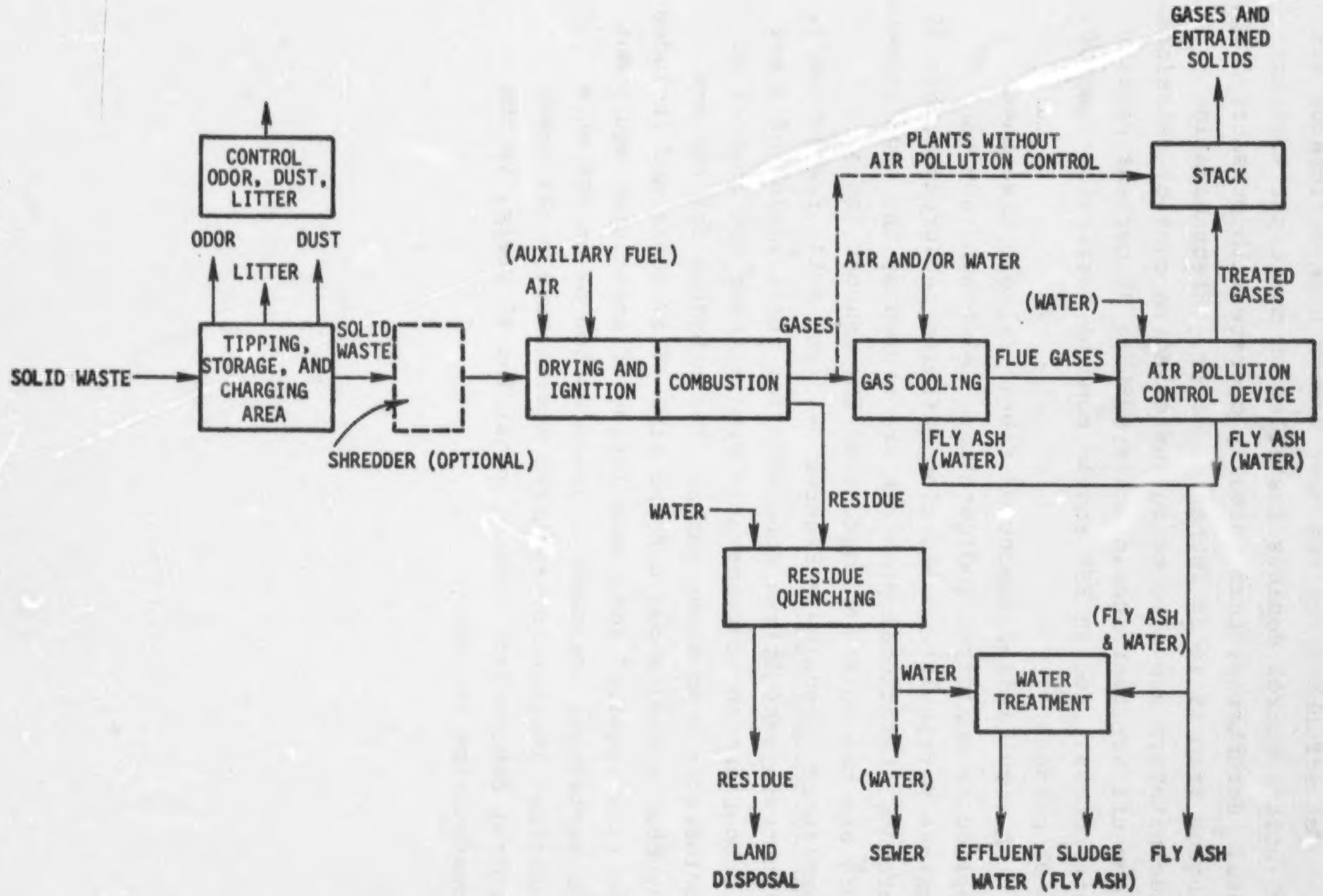
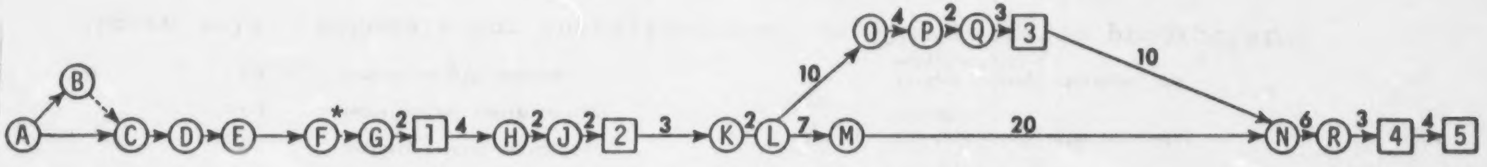

CONTROL ODOR, DUST, LITTER
ODOR
LITTER
DUST
SOLID WASTE
TIPPING, STORAGE, AND CHARGING AREA
SOLID WASTE
SHREDDER (OPTIONAL)
(AUXILIARY FUEL)
AIR
DRYING AND IGNITION
COMBUSTION
GASES
PLANTS WITHOUT AIR POLLUTION CONTROL
AIR AND/OR WATER
GAS COOLING
FLUE GASES
(WATER)
AIR POLLUTION CONTROL DEVICE
TREATED GASES
STACK
GASES AND ENTRAINED SOLIDS
FLY ASH (WATER)
FLY ASH (WATER)
RESIDUE
WATER
RESIDUE QUENCHING
(FLY ASH & WATER)
WATER
WATER TREATMENT
RESIDUE
LAND DISPOSAL
(WATER)
SEWER
EFFLUENT WATER
SLUDGE (FLY ASH)
FLY ASH

Figure 3-12. Municipal incineration process.

Wet scrubbers are the most common high-efficiency air pollution control devices installed on municipal incinerators. Scrubber systems normally operate with pressure drops ranging from 15 to 50 inches of water. Electrostatic precipitators are also being installed to control emissions. A venturi scrubber should achieve 80 to 95 percent particulate removal, and an ESP should control particulates by 90 to 95 percent.[5]

A very limited number of fabric filters have been applied to municipal incinerators. Although they can achieve particulate collection efficiencies greater than 98 percent, operational problems are caused by the high temperature and the moisture content of the exhaust gases.

Compliance Schedules - Figures 3-13 and 3-14, respectively, illustrate expeditious schedules for installation of a wet scrubber and an electrostatic precipitator for control of incinerator combustion gases. The schedule for the wet scrubber system shows a total time of 57 weeks and includes the time required for installation of associated equipment for wastewater treatment. Installation of an ESP on a municipal incinerator requires approximately 111 weeks. Control device fabrication, requiring 48 weeks, is the longest time increment.



* Refer to Chapter 2 for time increments A to G.

□ Milestones

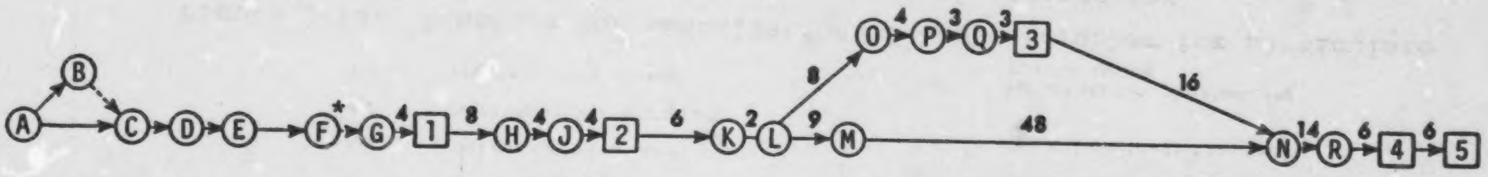
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	34
4	Date by which on-site construction or installation of emission control equipment is completed.	53
5	Date by which final compliance is achieved.	57

Activity designation	Activity description
A-B	Conduct source tests
A-C	Perform preliminary investigation
C-D	Evaluate control alternatives
D-E	Commit funds for total program
E-F	Prepare control plan and compliance schedule for agency
F-G	Agency reviews and approves plans
G-1	Finalize plans and specifications
1-H	Procure control device bids
H-J	Evaluate control device bids
J-2	Award control device contract
2-K	Prepare assembly drawings

Activity designation	Activity description
K-L	Review and approve assembly drawings
L-M	Prepare fabrication drawings
M-N	Fabricate control device
L-O	Prepare engineering drawings
O-P	Procure construction bids
P-Q	Evaluate construction bids
Q-3	Award construction contract
3-N	Initiate on-site construction
N-R	Install control device
R-4	Complete construction and system tie-in
4-5	Perform startup, shakedown, and emission testing

Figure 3-13. Schedule for installation of a wet scrubber for particulate pollutant control on a municipal incinerator.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	20
3	Date of initiation of on-site construction or installation of emission control equipment.	46
4	Date by which on-site construction or installation of emission control equipment is completed.	105
5	Date by which final compliance is achieved.	111

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-14. Schedule for installation of an electrostatic precipitator for particulate control on a municipal incinerator.

Sources of Additional Information

	Source	Type of information*
1.	Systems Study of Air Pollution from Municipal Incinerators. Volume I, II and III. Prepared by Arthur D. Little, Inc., for the U.S. Environmental Protection Agency, Washington, D.C. Publication No. APTD-1283, 1284, 1285. March 1970. 920 p.	P, E, C
2.	Oglesby, S. and G.B. Nichols. A Manual of Electrostatic Precipitator Technology. Part II-Application Areas. Prepared by Southern Research Institute for the National Air Pollution Control Administration, Cincinnati, Ohio. NTIS No. PB 196-381. August 1970. 875 p.	C
3.	Stear, J.R. Municipal Incineration: A Review of Literature. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-79. June 1971. 94 p.	P, E, C
4.	Air Pollution Aspects of Emission Sources: Municipal Incineration. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-92. May 1971. 101 p.	E, C
5.	Refuse Incineration. In: Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. p. 2.1-4.	P

6. Axetell, K. et al. Inspection Manual for the Enforcement of New Source Performance Standards: Municipal Incinerators. Prepared by PEDCo Environmental Specialists for the U.S. Environmental Protection Agency, Washington, D.C. Publication No. EPA 340/1-75-003. February 1975. 98 p. P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.2.2 Sludge Incinerators

Process Description - Sludge incinerators reduce by about 90 percent the volume of sludge generated by municipal wastewater treatment plants by burning the combustible content. Incineration destroys the organic matter in the sludge and leaves only an odorless, sterile ash suitable for landfill.

Figure 3-15 is a generalized schematic of a sludge treatment system.

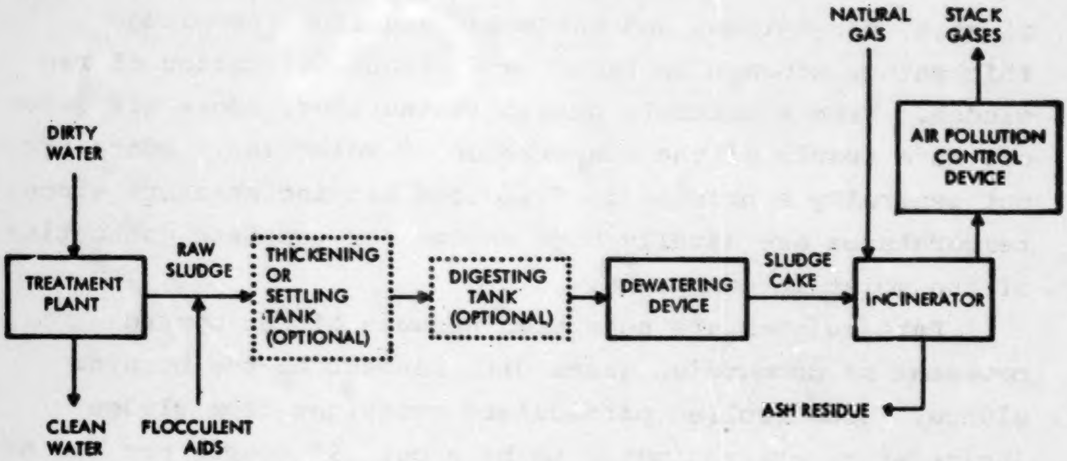

NATURAL GAS
STACK GASES
DIRTY WATER
AIR POLLUTION CONTROL DEVICE
RAW SLUDGE
THICKENING OR SETTLING TANK (OPTIONAL)
DIGESTING TANK (OPTIONAL)
SLUDGE CAKE
TREATMENT PLANT
DEWATERING DEVICE
INCINERATOR
ASH RESIDUE
CLEAN WATER
FLOCCULENT AIDS

Figure 3-15. Sludge treatment system.

The most prevalent types of sludge incinerators are multiple hearth and fluidized bed units. Capacities generally range up to 8000 pounds per hour of dry sludge. In multiple hearth units, the sludge enters the top of the furnace and is dried by the hot rising combustion gases. Then the sludge burns as it moves down through the lower hearths. Temperatures range from 600°F on the lower ash cooling hearth to 2000°F on the combustion hearths. In fluidized bed reactors, combustion takes place in a hot suspended bed of sand. Temperatures generally range from 1250 to 1500°F. An auxiliary fuel may be required in both types of furnace during start-up or when the moisture content of the sludge is too high to support combustion.

Atmospheric Emissions - Odors and particulate are the major emissions from a sludge incineration facility. Most of the odors emanate from pretreatment stages from the accumulation of grit, screenings, and skimmings and from raw sludge thickening, storage in tanks, and vacuum filtration of raw sludge. From a multiple hearth incinerator, odors are given off as a result of the evaporation of volatiles. Odors are not generally a problem in fluidized bed incinerators since temperatures are usually high enough for complete combustion of the volatile compounds.

Particulates are generated because of the upward movement of combustion gases with respect to the burning sludge. Uncontrolled particulate emissions from sludge incinerators are estimated to be about 194 pounds per ton of dry sludge. Particulate emissions into the atmosphere are almost entirely a function of control device efficiency. Emissions will increase if design temperatures are not maintained or if excess sludge is charged. Mercury and other more volatile metals may also be emitted if they are present in the sludge.

Other products of combustion (i.e. carbon monoxide, carbon dioxide, sulfur oxides, and nitrogen oxides) are not emitted in sufficient quantities to warrent concern.

Control Systems - Sludge incinerators are generally subject to particulate and opacity standards. Although odors are sometimes a problem, they are not typically regulated. A well-operated sludge incinerator will yield little odor if proper housekeeping procedures are practiced.

Water scrubbing is the most effective method for cleaning exhaust gases from sludge incinerators. Venturi, baffle plate, impingement, orifice, and cyclone type scrubbers are potentially effective for controlling particulate emissions. Venturi scrubbers with pressure drops of 20 to 30 inches water gauge and impingement towers have been used successfully to control particulate emissions. Normally a particulate removal efficiency of at least 97 percent is required to meet applicable regulations.[1]

Compliance Schedules - Figure 3-13 illustrates an expeditious schedule for installation of a venturi scrubber. Water treatment facilities should already be available at the sludge incinerator site. If a water treatment system is needed, the treatment facility and scrubber can be installed concurrently within the same time interval. The total time requirement is estimated to be 57 weeks, including a 20-week increment for control device fabrication.

Sources of Additional Information

	Source	Type of information*
1.	Devitt, T.W. and N.J. Kulujian. Inspection Manual for the Enforcement of New Source Performance Standards: Sewage Sludge Incinerators. Prepared by PEDCo-Environmental Specialists, Inc. for the U.S. Environmental Protection Agency, Washington, D.C. Publication No. EPA 340/1-75-004. February 1975. pp. 3-1 to 3-5.	P, E, C
2.	Hecht, N.L. et al. Characterization and Utilization of Municipal and Utility Sludges and Ashes. Volume II - Municipal Sludges. Prepared by University of Dayton Research Center for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. EPA 670/2-75-033b. May 1975. pp. 164-177.	P
3.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976.	E

*P = Process description
E = Emission rates
C = Control devices

3.2.3 Liquid Waste Incinerators

Process Description - Liquid waste incinerators burn liquids such as paint sludges, off-quality paints and inks, waste lubricating and cutting oils, partially polymerized plastic resins, cleanup solvents, pickling liquors, plating wastes, and degreaser bottoms. Generally, these liquids are destroyed on a load-by-load basis and are not blended to produce a feed having constant heating value and solids content. Figure 3-16 is a schematic of a typical liquid waste incineration process.

After the liquid wastes are screened or filtered to remove large solids, the liquids are injected with combustion air into a refractory-lined combustion chamber. Combustion of some low-Btu wastes may require supplementary fuel. Complete combustion of organic materials requires temperatures above 1600°F and retention times greater than 0.5 second.

Solids removed by filtration and ash removed from the incinerator are disposed of by landfill.

Atmospheric Emissions - Emissions from liquid waste incinerators depend on the type of liquid waste being burned and the completeness of combustion. Particulate emissions have been estimated to range from 0.075 to 0.37 pound per gallon burned.[1,2] Because the sulfur content of most liquid wastes is low, emissions of SO_2 are not a problem. Hydrocarbon emissions can be significant if the incinerator temperature is below 1600°F or retention times are less than 0.5 second.[2] Hydrogen chloride emissions can be generated by burning of materials such as chlorinated solvents and pickling liquors.

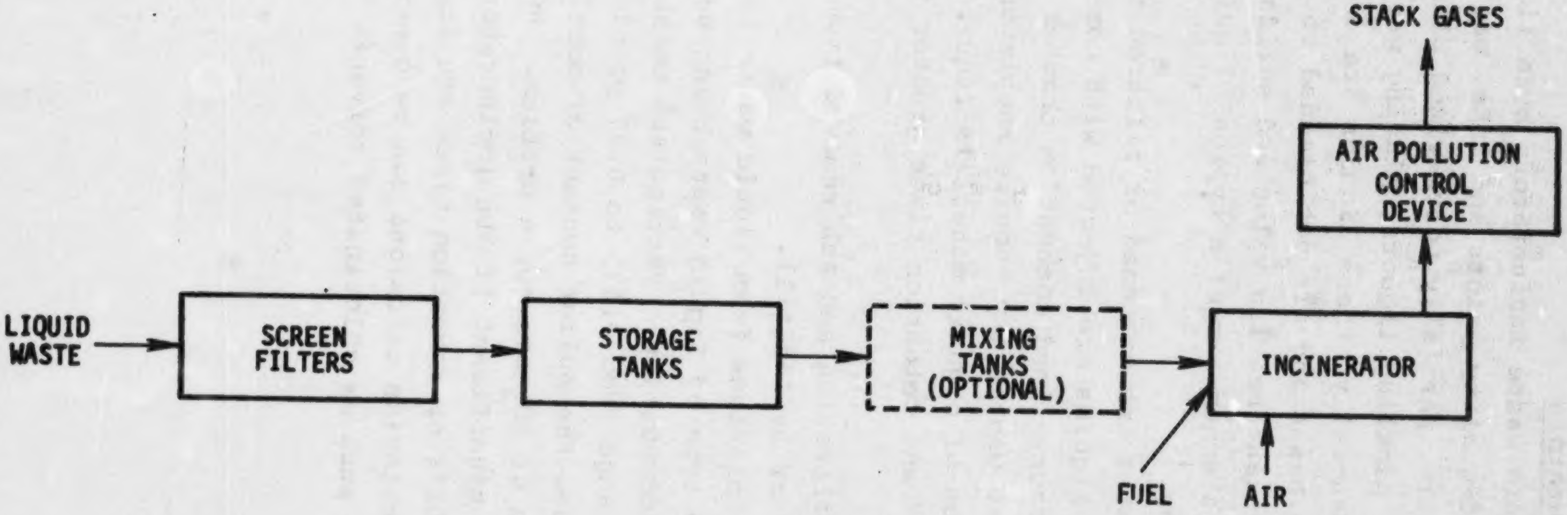

LIQUID WASTE
SCREEN FILTERS
STORAGE TANKS
MIXING TANKS (OPTIONAL)
INCINERATOR
FUEL
AIR
AIR POLLUTION CONTROL DEVICE
STACK GASES

Figure 3-16. Liquid incineration process.

Control Systems - Wet scrubbing is the most effective method for controlling particulate emissions from a liquid waste incinerator. If a venturi is used, pressure drops of over 40 inches water gauge may be required to meet applicable particulate regulations.[1]

Hydrocarbon emissions can be reduced by increasing the efficiency of combustion through use of lower feed rates and higher operating temperatures. If hydrogen chloride emissions are a problem, the incineration facility may be required to stop burning the liquids containing excess chlorides.

Compliance Schedules - Figure 3-13 shows an expeditious schedule for installation of a wet scrubber on any type of incinerator. Concurrent installation of associated equipment for wastewater treatment would not significantly change this schedule. An estimated 54 weeks is required for compliance, including 20 weeks for control device fabrication.

Sources of Additional Information

	Source	Type of information*
1.	Ponder, T.C. Particulate Emission Control - Robert Ross & Sons, Inc., Grafton, Ohio. Prepared by PEDCo-Environmental Specialists, Inc. for Ohio Environmental Protection Agency. June 1974. 19 p.	P, E, C
2.	Hall, F.D. and T.C. Ponder. Report on Emission Controls at the Liquid Disposal Company, Norwalk, Ohio. Prepared by PEDCo-Environmental Specialists, Inc. for Ohio Environmental Protection Agency. July 1974. 18 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.2.4 Waste Disposal in Existing Boilers

Process Description - Many companies in the United States are considering combustion of refuse along with other fuel in existing boilers. In Europe, where several boilers are designed to accommodate refuse, this technique has been used successfully since 1965.

For burning in an existing boiler, the refuse must first be separated and classified. A typical processing plant is shown in Figure 3-17. After separation, the shredded combustible materials are sent to the boiler, the ferrous metals are hauled to a steel mill, and the nonmagnetic metals, glass, and other waste are further separated or sent to a landfill. Figure 3-18 shows a schematic of refuse being fed to a boiler. The refuse can supply 10 to 15 percent or more of the total fuel burned in industrial or utility boilers. The heat content of dry refuse ranges from 6000 to 8000 Btu per pound.

Atmospheric Emissions - Tests performed at a demonstration plant of Union Electric in St. Louis indicated no significant changes in gaseous or particulate concentration levels when refuse and coal were fired together in the utility boiler. However, the resistivity and the chloride content of the particulate had increased slightly.

Control Systems - Currently marketed control systems will generally be adequate for boilers burning a combination of refuse and coal. Scrubbers, ESP's or baghouses are all applicable. However, modifications to existing boiler control equipment may be necessary because of the increased resistivity and the change of chemical properties of the flyash.

Compliance Schedules - If controls are needed, the installation times will be the same as those determined for utility and industrial boilers, discussed in Section 3.1.

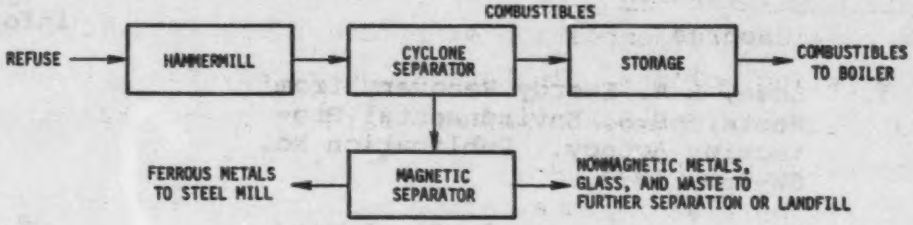

REFUSE
HAMMERMILL
COMBUSTIBLES
CYCLONE SEPARATOR
STORAGE
COMBUSTIBLES TO BOILER
FERROUS METALS TO STEEL MILL
MAGNETIC SEPARATOR
NONMAGNETIC METALS, GLASS, AND WASTE TO FURTHER SEPARATION OR LANDFILL

Figure 3-17. Refuse processing plant.

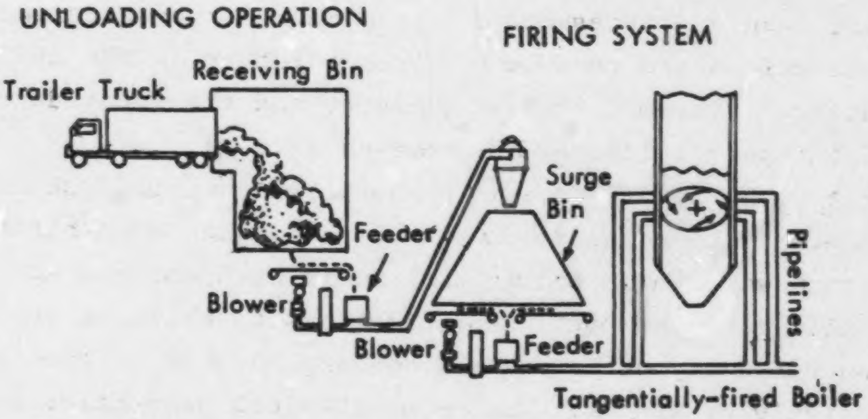

UNLOADING OPERATION
Receiving Bin
Trailer Truck
FIRING SYSTEM
Surge Bin
Feeder
Blower
Pipelines
Blower
Feeder
Tangentially-fired Boiler

Figure 3-18. Union Electric Co. facilities for receiving, storing, and burning refuse.

Sources of Additional Information

	Source	Type of information*
1.	Lowe, R.A. Energy Recovery from Waste. U.S. Environmental Protection Agency. Publication No. SW-36. 1973.	P
2.	Shannon, L.J. et al. St. Louis/Union Electric Refuse Firing Demonstration, Air Pollution Test Report. Prepared by Midwest Research Institute for the U.S. Environmental Protection Agency, Washington, D.C. Publication No. EPA 650/2-74-073. August 1974. 108 p.	P, E, C

*P = Process description
E = Emission rates
C = Control device

3.2.5 Sanitary Landfill

Process Description - Sanitary landfilling is a method of disposing of solid wastes on land by spreading them in thin layers, compacting them to the smallest practical volume, and covering them with soil each working day in a manner that protects the environment. No wastes are burned at a sanitary landfill. Wastes are brought to landfill sites in trucks and dumped in designated areas. These wastes are compacted by passing over the material with bulldozers or other heavy machinery. Easily compactible wastes, bulky wastes, dead animal wastes, volatile and flammable wastes, and other waste categories are dumped in different areas of the landfill. Radioactive and explosive wastes are not allowed in most landfills.

At the end of each working day, more often if necessary, the collected wastes are covered with approximately 6 inches of compacted earth. This cover layer is intended to eliminate the attraction of flies, rodents, and scavenging birds; to minimize moisture entering fill; to provide for containment or release of waste gases, depending on the use of the completed landfill; and to control blowing of paper or other litter.

Atmospheric Emissions - Emissions from landfills are organic gases of decomposition (mainly carbon dioxide and methane), fugitive dust, and windborne litter. Methane emissions can be an explosion hazard if allowed to reach concentrations of 5 to 15 percent in the presence of oxygen; such concentrations can be reached by accumulation of gas in nearby buildings. Fugitive dust emissions depend on the type and moisture content of the cover soil and on wind conditions. Litter can be a problem on windy days.

Control Systems - Good landfill design and proper operation are the best methods for control of emissions from landfills. Generally, accumulation of decomposition gases present no problems if the cover material is more permeable than the surrounding soil, allowing dispersal of the gases over a large area. If the cover soil is relatively impermeable, gases can be vented to a safe area by use of gravel or pipe vents. Fugitive dust can be minimized by wetting of roadways and cover soils. Planting of trees and shrubs along the landfill boundaries will help contain dust and litter within the site. Litter can also be controlled by cleaning the site frequently and by erecting fences to retain the blowing paper.

Compliance Schedules - A properly designed and operated landfill should be in compliance with applicable regulations from the beginning of operation until landfilling is completed. Any problems can be resolved within 2 weeks of notification by improving site cleanup and maintenance practices.

Sources of Additional Information

	Source	Type of information*
1.	Brunner, D.R. and D.J. Keller. Sanitary Landfill Design and Operation. U.S. Environmental Protection Agency. Publication No. SW-65ts. 1972. 59 p.	P, E, C
2.	Residual Waste Best Management Practices: A Water Planner's Guide to Land Disposal. Prepared by PEDCo-Environmental Specialists, Inc. for the Water Planning Division, U.S. Environmental Protection Agency, Washington, D.C. Publication No. EPA 440/9-76-022. August 1976. 238 p.	P

*P = Process description
E = Emission rates
C = Control devices

3.3 EVAPORATION SOURCES

3.3.1 Surface Coating

Process Description - Surface coating operations consist of applying a coat of paint or varnish to an object, evaporating the solvent by application of heat, and finally hardening the coated surface by subjecting it to high temperatures. Coating operations range from small, manually operated units to large facilities for spraying and dipping auto bodies. This classification also includes coating and decorating of cans.

Large-scale solvent evaporation and baking operations are conducted inside an oven, where heat is supplied by banks of infrared lamps or by direct or indirect combustion of natural gas or fuel oil. During the surface coating and drying operation, most of the volatile constituents of the coated material evaporate and are released to the atmosphere if air pollution controls are not applied.

Simplified schematics of surface coating operations, with direct-fired afterburner and adsorption systems to control hydrocarbon emissions, are shown in Figures 3-19 and 3-20. Freshly coated pieces enter the oven, in which the pressure is maintained slightly below atmospheric to prevent leakage of solvent vapors into the room and to draw in enough room air to prevent the formation of explosive mixtures. Most of the volatile components of the coating are released shortly after the object enters the oven. This mixture of hydrocarbons and air is withdrawn from the oven by means of a blower.

Atmospheric Emissions - Hydrocarbons generated in the coating and drying processes are the primary emissions of concern. The paint spraying operations generate some particulate emissions, but these are generally controlled near

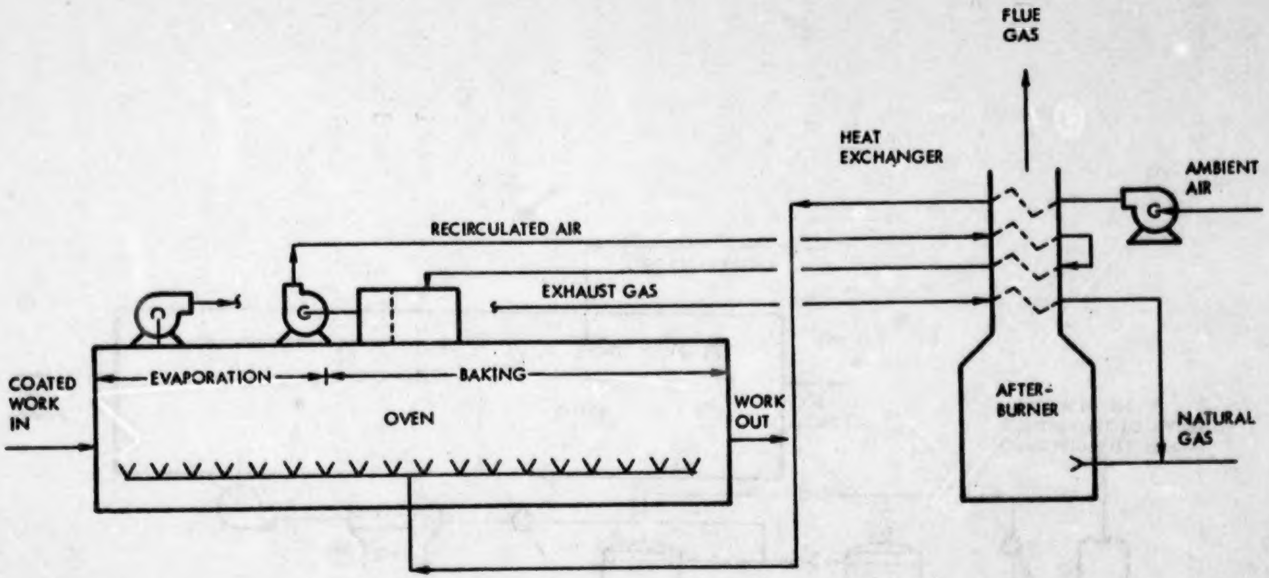

FLUE GAS
HEAT EXCHANGER
AMBIENT AIR
RECIRCULATED AIR
EXHAUST GAS
COATED WORK IN
EVAPORATION
BAKING
OVEN
WORK OUT
AFTER-BURNER
NATURAL GAS

Figure 3-19. Surface coating operation with afterburner control system.

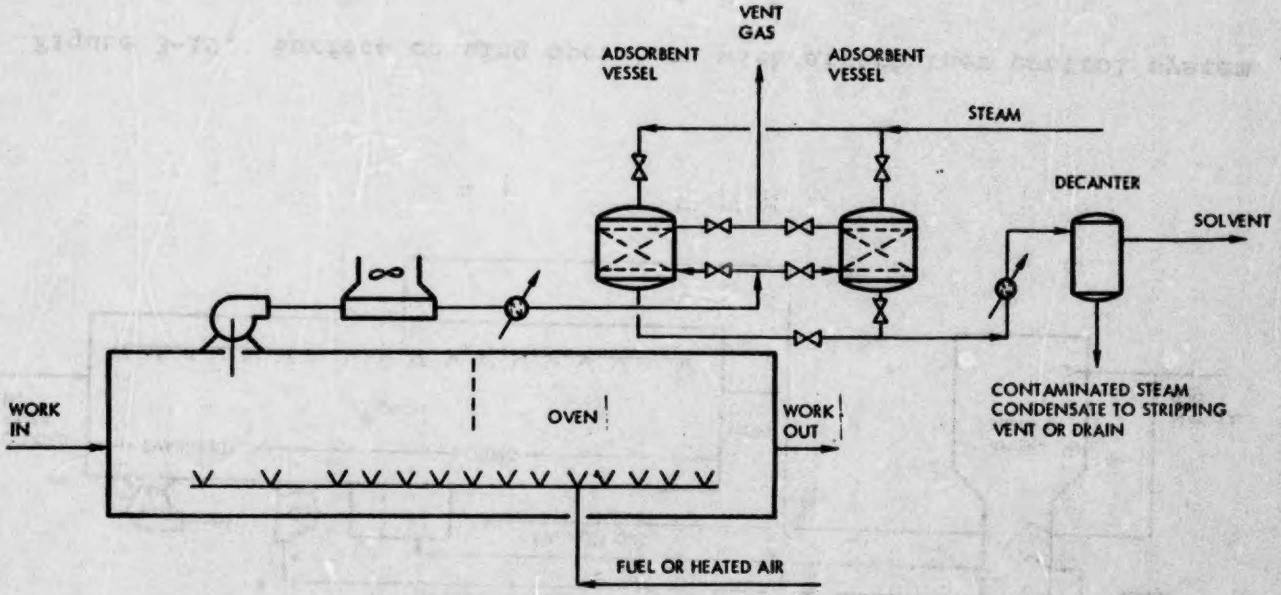

VENT GAS
ADSORBENT VESSEL
ADSORBENT VESSEL
STEAM
DECANTER
SOLVENT
CONTAMINATED STEAM CONDENSATE TO STRIPPING VENT OR DRAIN
WORK IN
OVEN
WORK OUT
FUEL OR HEATED AIR

Figure 3-20. Surface coating operation with adsorption control system.

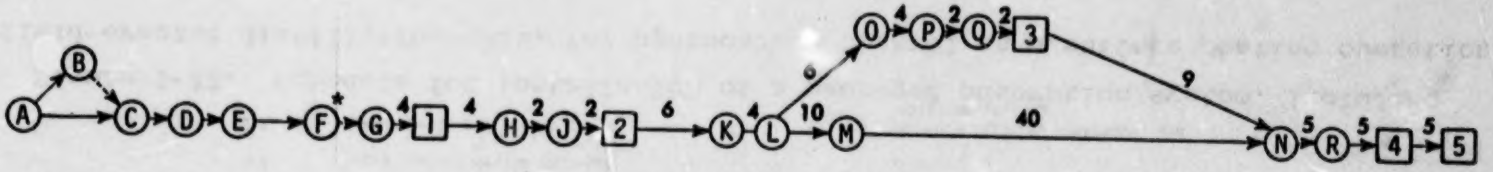
the point of application by fiberglass filters and/or a water curtain built into the exhaust system.

The type and quantity of hydrocarbon emissions vary directly with the type and quantity of solvent in the coating. The solvent content often amounts to about 50 percent of the total weight of the coating material. Overall process emissions can be estimated by material balance calculations, since all of the solvent must evaporate in some phase of the process. In direct-fired ovens, however, some solvent vapor is burned.

Control Systems - Hydrocarbon emissions can be minimized by using control equipment or by reducing the solvent content of the coating. Process changes that reduce emissions include the use of "exempt" solvents and water-base coatings, and the setting or drying of coatings by application of other types of energy (e.g. infrared, ultraviolet) instead of heat, supplied by direct firing. Where process changes are unfeasible, emissions can be reduced by use of control equipment such as direct-fired afterburners, catalytic afterburners, and adsorption systems. Selection of an air pollution control system depends on several factors, including the value of the recovered solvent and the availability and cost of fuel oil or natural gas for incineration. Generally, in small operations where the flow rate of vented gas is less than 5000 scfm emissions are controlled with direct-fired afterburners without heat recovery. In large operations, some of which generate emissions in the tens of thousands of scfm control is achieved by direct-flame incineration with heat recovery, or catalytic burners. When the solvent is worth recovering, an adsorption system may be incorporated into the process.

Compliance Schedule - Figures 3-21 and 3-22 illustrate expeditious schedules for installation of a field-erected adsorbtion system and a skid-mounted "package" adsorption system, respectively, on a surface coating operation. Selection of a system depends upon such factors as nature of the recovered solvent and volume of vented gas. Figure 3-23 represents an expeditious schedule for installation of an afterburner on a surface coating operation.

A compliance schedule for switching to an exempt solvent is highly variable. Testing to determine alternative solvents compatible with the process could take several weeks. After an acceptable alternative solvent has been determined and a supplier has been found, the changeover can be made within a week of receiving the new solvent. Shortages of many exempt solvents could delay the changeover for several weeks.



* Refer to Chapter 2 for time increments A to G.

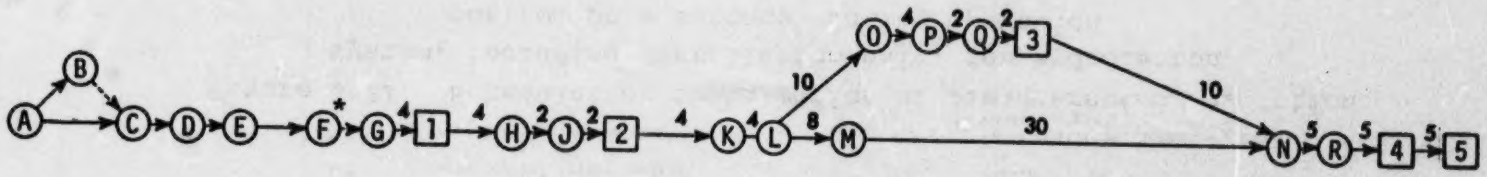
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	36
4	Date by which on-site construction or installation of emission control equipment is completed.	82
5	Date by which final compliance is achieved.	87

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-21. Schedule for installation of field-erected adsorption system, including distillation unit, for hydrocarbon control on a surface coating operation.



* Refer to Chapter 2 for time increments A to G.

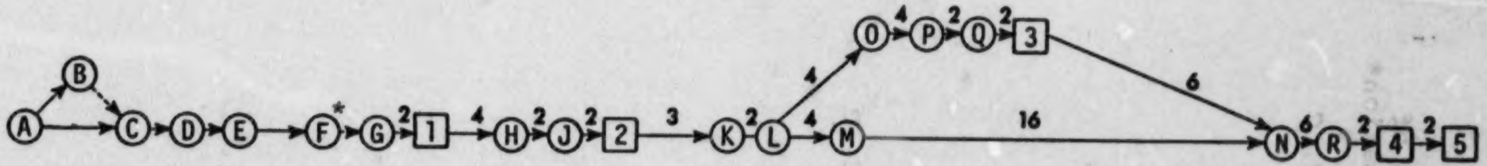
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	68
5	Date by which final compliance is achieved.	73

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-22. Schedule for installation of a packaged adsorption system, including field-erected distillation unit, for hydrocarbon control on a surface coating operation.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	27
4	Date by which on-site construction or installation of emission control equipment is completed.	43
5	Date by which final compliance is achieved.	45

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-23. Schedule for installation of an afterburner for hydrocarbon control on a surface coating operation.

Sources of Additional Information

	Source	Type of information*
1.	Surface Coating Operations. In: Air Pollution Engineering Manual, 2nd ed., Danielson, J.A. (ed.). U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. pp 855-871.	P, E, C
2.	Rolke, R.W. et al. Afterburner Systems Study. Prepared by Shell Development Company for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. PB 212 560. August 1972. 512 p.	C
3.	Gadomski, R.R. et al. Evaluations of Emissions and Control Technologies in the Graphic Arts Industries. Prepared by Graphic Arts Technical Foundation for the U.S. Public Health Service, Cincinnati, Ohio NTIS No. PB 195-770.	P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.3.2 Petroleum Storage

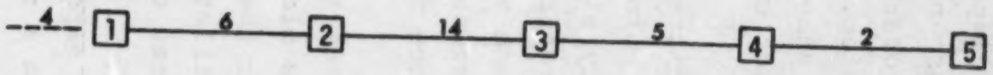
Process Description - Storage vessels can be classified as either closed-storage or open-storage tanks. Pressure vessels used for storage of volatile hydrocarbons are most commonly cylinders, spheres, or spheroids. Fixed-roof tanks or lifted-roof conservation tanks are used for storage of low-volatility liquids. Floating-roof tanks and diaphragm conservation tanks minimize the vapor space and are normally used for storage of volatile fractions or of hydrocarbons that present potential hazards for fire or explosion.

Open-storage vessels, found in a variety of shapes, are now used infrequently because of safety and product conservation considerations.

Atmospheric Emissions - Hydrocarbon vapors are emitted as a result of volatilization of the stored material. Since cylindrical flat-roof tanks operate at only a very slight positive pressure, the diurnal atmospheric temperature changes cause expansion and contraction of the tank vapor space, and hence emissions or "breathing." Emissions are particularly significant in fixed-roof tanks, since filling also causes breathing.

Control Systems - Effective control methods include the use of floating roofs, use of devices such as plastic blankets and spheres to reduce the exposed surface area or the tank volume, and use of vapor recovery systems. Installation of an internal floating roof is the most commonly used control technique for existing tankage.

Compliance Schedules - Figure 3-24 represents an expeditious schedule for installation of a floating-roof with a double deck on an existing storage tank.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	24
4	Date by which on-site construction or installation of emission control equipment is completed.	29
5	Date by which final compliance is achieved.	31

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Note: For tanks 150 to 200 ft. in diameter, add 10 weeks to Steps 3-4.

Figure 3-24. Schedule for installation of an internal floater for hydrocarbon control on an existing storage tank of diameter less than 150 ft.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., ed. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, E, C
2.	Nelson, W.L. Petroleum Refinery Engineering. McGraw-Hill, New York. 1958. 960 p.	P, C
3.	Atmospheric Emissions from Petroleum Refineries. A Guide for Measurement and Control. U.S. Public Health Service, Cincinnati, Ohio. NTIS No. PB 198-096. 1960. 64 p.	E

*P = Process description
E = Emission rates
C = Control devices

3.4 CHEMICAL PROCESSES

3.4.1 Nitric Acid

Process Description - All nitric acid produced commercially is manufactured by the ammonia oxidation process. Despite many variations in operating details, three basic steps are common to all plants producing nitric acid: (1) oxidation of ammonia to nitric oxide, followed by (2) oxidation of nitric oxide to the dioxide, and finally (3) absorption of nitrogen dioxide in water to produce nitric acid with the release of additional nitric oxide.

A schematic flow diagram for production of nitric acid by the ammonia oxidation pressure process is shown in Figure 3-25. In this process ammonia vapors are mixed with preheated compressed air and passed over a platinum catalyst to form nitrogen oxide and water. The heat content of the gas, primarily due to the exothermic reaction, is recovered by preheating the absorber tail gases and the process air, and finally by passing the gas through a waste heat boiler to generate steam. The gases are then filtered to recover the valuable platinum catalyst dust and are further cooled in a water cooler. The successive oxidations and hydrations of the nitric oxide are conducted with continuous water cooling in a stainless steel absorption tower.

The tail gas leaving the absorption tower normally contains 0.2 to 0.3 percent nitrogen oxides by volume. In an uncontrolled plant these gases are vented after passing through an expander turbine for energy recovery.

Atmospheric Emissions - Emissions of nitrogen oxides from nitric acid plants are estimated to be about 43 pounds per ton of acid produced. This value corresponds to about 3000 ppm NO_x (by volume) in the exit gas stream. Nitrogen dioxide, distinguished by its opaque reddish-brown color,

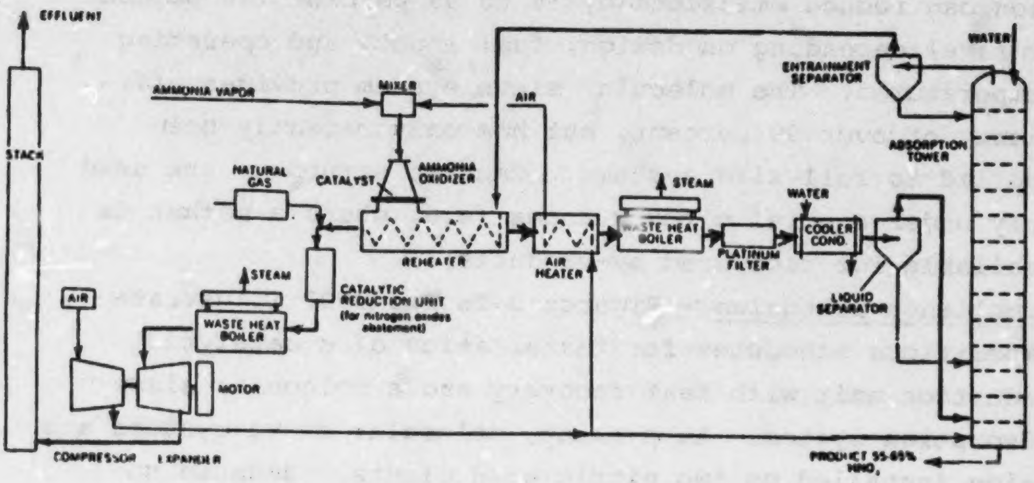
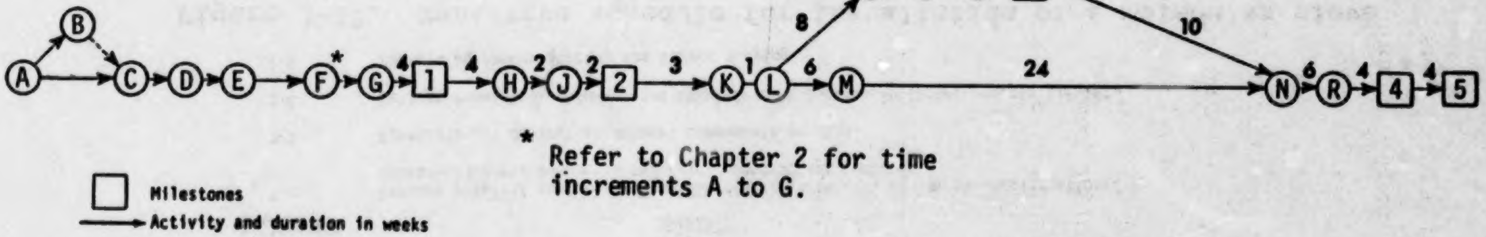

EFFLUENT
STACK
AMMONIA VAPOR
MIXER
AIR
WATER
ENTRAINMENT SEPARATOR
ABSORPTION TOWER
NATURAL GAS
CATALYST
AMMONIA OXIDIZER
STEAM
WATER
REHEATER
AIR HEATER
WASTE HEAT BOILER
PLATINUM FILTER
COOLER COND.
LIQUID SEPARATOR
STEAM
CATALYTIC REDUCTION UNIT (for nitrogen oxides abatement)
AIR
WASTE HEAT BOILER
MOTOR
COMPRESSOR
EXPANDER
PRODUCT 55-65% HNO₃

Figure 3-25. Nitric acid manufacture by the pressure process, with catalytic tail gas control system.

makes up approximately 50 percent of this emission. The remainder of the gas is the colorless nitric oxide compound. Control Systems - Techniques for nitrogen oxides control include catalytic reduction and use of molecular sieve adsorption systems and caustic scrubbers. Catalytic reduction can reduce emissions by 36 to 99 percent (80 percent average) depending on design, fuel input, and operating temperatures. The molecular sieve system provides efficiency of over 99 percent, but has only recently been applied to full-size systems. Caustic scrubbers are used only under special circumstances (e.g. where a market is available for recovered by-products).

Compliance Schedules - Figures 3-26 and 3-27 illustrate expeditious schedules for installation of a catalytic reduction unit with heat recovery and a molecular sieve adsorption system. At present, molecular sieve systems are being installed on two nitric acid plants. Because no nitric acid plant is operating with molecular sieves, the schedule is tentative.

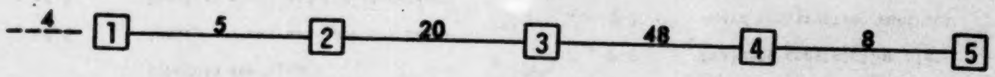


* Refer to Chapter 2 for time increments A to G.

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	32
4	Date by which on-site construction or installation of emission control equipment is completed.	56
5	Date by which final compliance is achieved.	60

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-26. Schedule for installation of a catalytic reduction unit with waste heat recovery for nitrogen oxide control on a nitric acid plant.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	9
3	Date of initiation of on-site construction or installation of emission control equipment.	29
4	Date by which on-site construction or installation of emission control equipment is completed.	77
5	Date by which final compliance is achieved.	85

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-27. Tentative schedule for installation of a molecular sieve adsorption system for nitrogen oxide control on a nitric acid plant.

Sources of Additional Information

	Source	Type of information*
1.	Kirk-Othmer Encyclopedia of Chemical Technology, 2nd ed. Volume 13. Interscience Publishers, New York, 1967. p. 796-814.	P
2.	Atmospheric Emissions from Nitric Acid Manufacturing Processes. National Center for Air Pollution Control, Cincinnati, Ohio. Publication No. AP-27. 1966. 96 p.	P, E, C
3.	Background Information for Proposed New-Source Performance Standards: Steam Generators, Incinerators, Portland Cement Plants, Nitric Acid Plants, and Sulfuric Acid Plants. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. PB 202-459. August 1971. 50 p.	E, C
4.	Air Pollution Aspects of Emission Sources: Nitric Acid Manufacturing. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-93. May 1971. 37 p.	E, C

*P = Process description
E = Emission rates
C = Control devices

3.4.2 Phosphoric Acid

Process Description - Phosphoric acid is produced by two basic methods, the wet process and the thermal process. In the wet process, phosphate rock is treated with sulfuric acid. The ensuing chemical reactions result in the formation of phosphoric acid and the precipitation of calcium sulfate. The latter is filtered off, and the acid is concentrated from about 32 percent P_2O_5 to about 54 percent P_2O_5. A simplified flow diagram is shown in Figure 3-28.

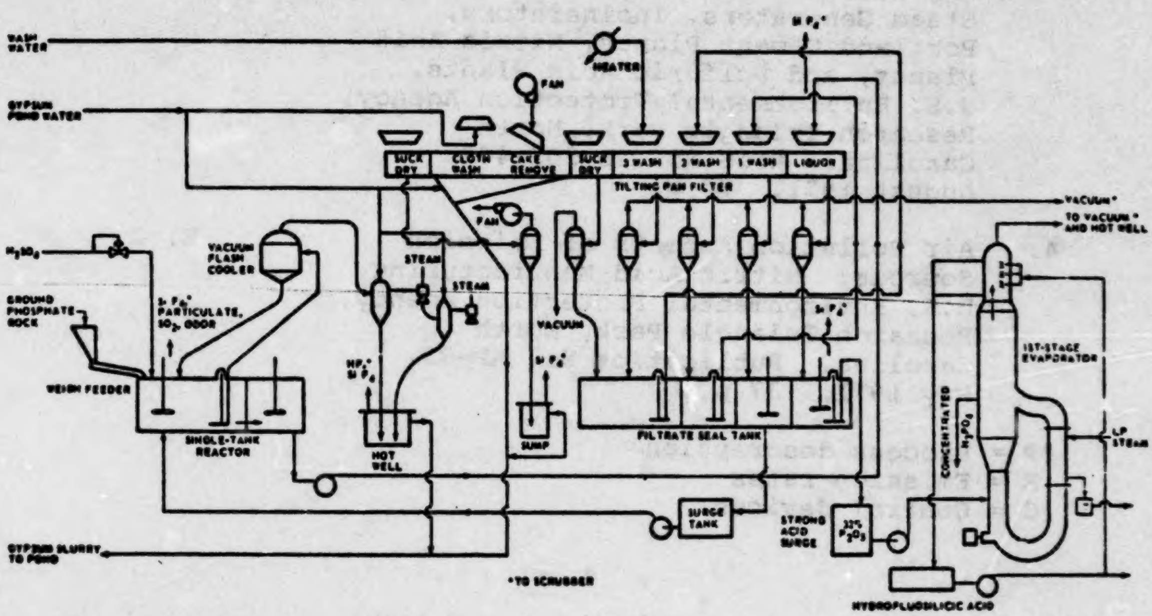

WASH WATER
HEATER
SiF_4*
FAN
GYPSUM POND WATER
SUCK DRY
CLOTH WASH
CAKE REMOVE
SUCK DRY
3 WASH
2 WASH
1 WASH
LIQUOR
TILTING PAN FILTER
VACUUM*
TO VACUUM* AND HOT WELL
FAN
H_2SO_4
VACUUM FLASH COOLER
STEAM
STEAM
GROUND PHOSPHATE ROCK
SiF_4* PARTICULATE, SO_2, ODOR
VACUUM
SiF_4*
1ST-STAGE EVAPORATOR
WEIGH FEEDER
HF_4* SiF_4
SiF_4*
SINGLE-TANK REACTOR
HOT WELL
SUMP
FILTRATE SEAL TANK
CONCENTRATED H_3PO_4
LP STEAM
SURGE TANK
STRONG ACID SURGE
32% P_2O_5
GYPSUM SLURRY TO POND
*TO SCRUBBER
HYDROFLUOSILICIC ACID

Figure 3-28. Manufacture of phosphoric acid by wet process.

In the thermal process, phosphoric acid is produced from elemental phosphorous. Three basic steps are involved: (1) burning the molten phosphorus in a suitable chamber to produce phosphorus pentoxide; (2) hydrating the phosphoric acid mist; (3) removal of the phosphoric acid mist from the gas stream. A simplified flow diagram of the major steps in the manufacture of phosphoric acid by the thermal process is shown in Figure 3-29.

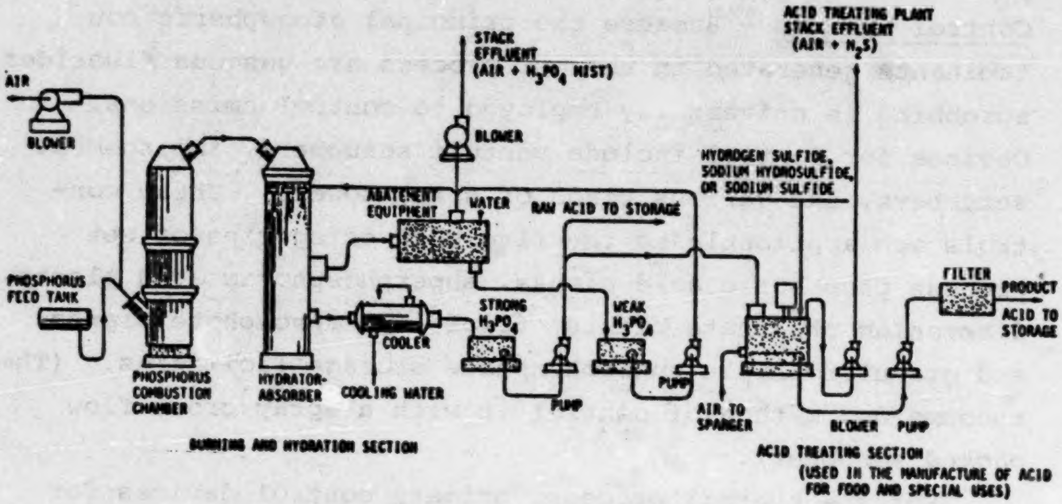

AIR
BLOWER
STACK EFFLUENT (AIR + H_3PO_4 MIST)
BLOWER
ACID TREATING PLANT STACK EFFLUENT (AIR + H_2S)
HYDROGEN SULFIDE, SODIUM HYDROSULFIDE, OR SODIUM SULFIDE
ABATEMENT EQUIPMENT
WATER
RAW ACID TO STORAGE
PHOSPHORUS FEED TANK
FILTER
PRODUCT
ACID TO STORAGE
STRONG H_3PO_4
WEAK H_3PO_4
COOLER
PUMP
PUMP
PHOSPHORUS COMBUSTION CHAMBER
HYDRATOR-ABSORBER
COOLING WATER
AIR TO SPARGER
BLOWER
PUMP
BURNING AND HYDRATION SECTION
ACID TREATING SECTION (USED IN THE MANUFACTURE OF ACID FOR FOOD AND SPECIAL USES)

Figure 3-29. Manufacture of phosphoric acid by thermal process.

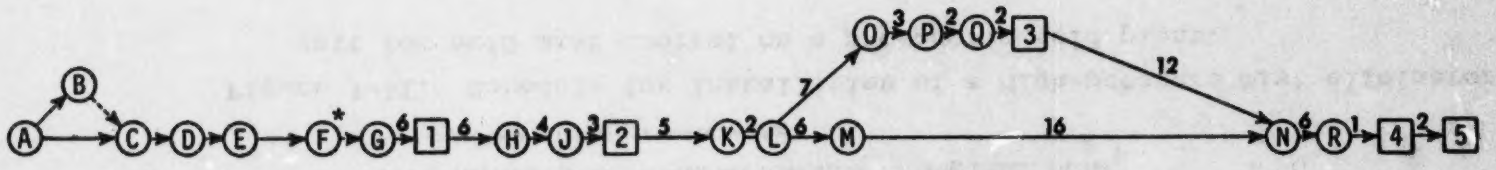
Atmospheric Emissions - Emissions of most concern in the wet process are the fluoride compounds liberated from the rock by the sulfuric acid. These consist of hydrogen fluoride, silicon tetrafluoride and various products of reaction and decomposition of the latter. Most phosphate rock contains 3.5 to 4 percent fluorine, and half of this may be volatilized in the processing. Fluorides may be emitted from exposed surfaces of reaction slurry, from aqueous solutions of fluoride compounds, and from evaporation processes.

The major atmospheric contaminant from the thermal process is phosphoric acid mist discharged in the absorber exit gas. This gas stream also contains water vapor and trace amounts of nitrogen oxides. Another important emission is the discharge gas from the acid-treating tank. These emissions are intermittent and range from 10 to 2500 parts per million of hydrogen sulfide.

Control Systems - Because the principal atmospheric contaminants generated in the wet process are gaseous fluorides, scrubbing is universally employed to control emissions. Devices for control include venturi scrubbers, impingement scrubbers, and various kinds of spray towers. These controls are applicable to the five NSPS categories of wet process phosphoric acid plants, superphosphoric acid plants, diammonium phosphate plants, triple superphosphate plants, and granular triple superphosphate storage facilities. (The recommended method of control is with a spray cross flow packed scrubber).

For the thermal process, primary control devices for control of emissions of acid mist include high-pressure wire-mesh eliminators and high-efficiency glass-fiber mist eliminators.

Compliance Schedules - Figure 3-30 illustrates an expeditious schedule for installing a wet scrubber system on a wet process or thermal process plant. An expeditious schedule for installation of a high-efficiency mist eliminator is shown in Figure 3-31.



* Refer to Chapter 2 for time increments A to G.

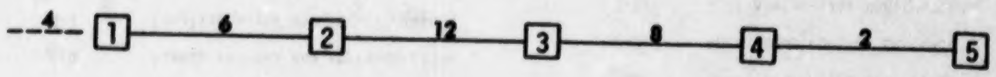
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	40
4	Date by which on-site construction or installation of emission control equipment is completed.	59
5	Date by which final compliance is achieved.	61

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-30. Schedule for installation of a wet scrubber system for gaseous and particulate fluoride control on a phosphoric acid plant.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	22
4	Date by which on-site construction or installation of emission control equipment is completed.	30
5	Date by which final compliance is achieved.	32

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-31. Schedule for installation of a high-pressure mist eliminator unit for acid mist control on a phosphoric acid plant.

Sources of Addition Information

	Source	Type of information*
1.	Atmospheric Emissions from Wet-Process Phosphoric Acid Manufacture. Prepared by Manufacturing Chemists' Association, Inc. and Public Health Service for National Air Pollution Control Administration, Raleigh, North Carolina. Publication No. AP-57. April 1970. 98 p.	P, E, C
2.	Atmospheric Emissions from Thermal-Process Phosphoric Acid Manufacture. Prepared by Manufacturing Chemists' Association, Inc. and Public Health Service for National Air Pollution Control Administration, Raleigh, North Carolina. Publication No. AP-48. October 1968. 72 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.4.3 Sulfuric Acid

Process Description - Essentially all sulfuric acid is produced by the contact process shown schematically in Figure 3-32 for a single absorption type sulfur burning plant. Sulfur or sulfur-containing raw materials (e.g. spent acid) are burned to form SO_2, which is then catalytically oxidized in a converter to SO_3. The heat liberated in the converter reaction is removed in several stages by intermediate gas cooling. The exit gas from the converter is cooled, and the SO_3 is absorbed in a circulating stream of 98 percent H_2SO_4.

Variations in the contact process are due primarily to differences in the sulfur feedstock. Units operating with spent acid, sludge, H_2S or smelter tail gas are more complicated than sulfur-burning plants since these feed streams are contaminated. After burning the feed stock in these "wet gas" plants, or when testing smelter gases, the resulting SO_2 gas or SO_2 rich gas stream requires additional cleaning and cooling to remove particulate, acid mist, and excessive water vapor.

Atmosheric Emissions - SO_2 emissions vary inversely with the SO_2-to-SO_3 conversion efficiency. For older sulfur-burning plants with three-stage converters, conversion efficiencies are typically 95 to 96 percent, which correspond to emissions of 55 to 70 pounds of SO_2 per ton of acid produced. Conversion efficiencies of four-stage converters range from 96 to 98 percent, with SO_2 emissions between 26 and 55 pounds per ton. Dual absorption plants, discussed in this section under Control Systems, can achieve conversion efficiencies in excess of 99 percent; the resulting SO_2 emissions usually range between 1 and 4 pounds per ton of acid on plants subject to new source performance standards. For

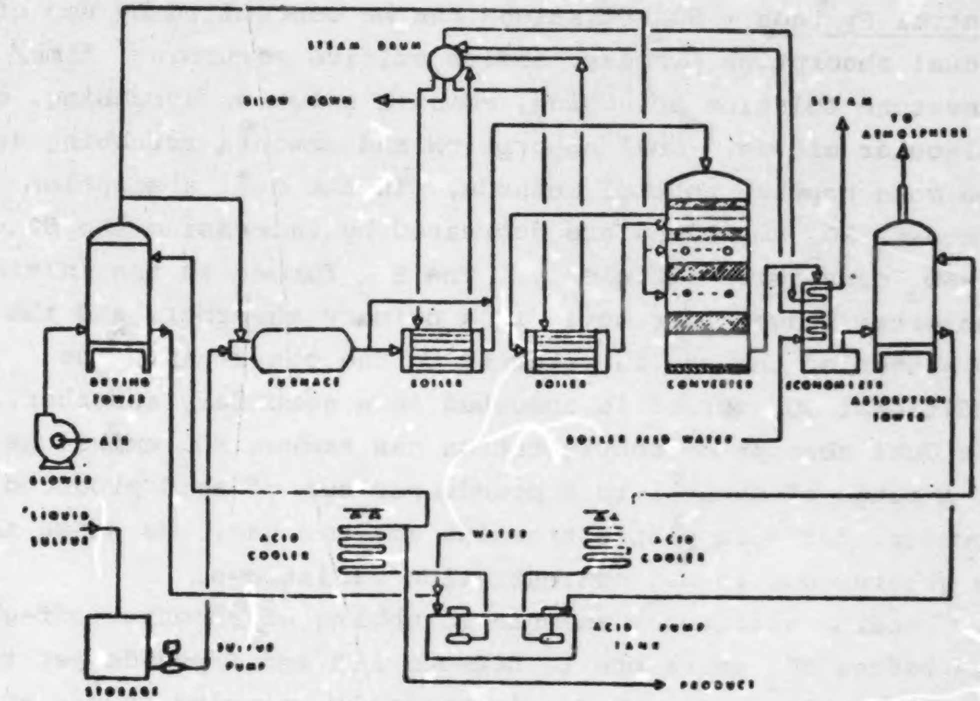

STEAM DRUM
BLOW DOWN
STEAM
TO ATMOSPHERE
DRYING TOWER
FURNACE
BOILER
BOILER
CONVERTER
ECONOMIZER
ABSORPTION TOWER
AIR
BLOWER
BOILER FEED WATER
LIQUID SULFUR
ACID COOLER
WATER
ACID COOLER
ACID PUMP TANK
SULFUR PUMP
STORAGE
PRODUCT

Figure 3-32. Contact process single absorption sulfuric acid plant burning elemental sulfur.

acid plants testing smelter tail gas, variations in SO_2 inlet concentrations make it difficult to reduce emissions to less than 650 ppm.

Acid mist emissions are also significant, especially for plants producing oleum or using sulfur feedstocks other than elemental sulfur. If uncontrolled, emissions range between 0.5 and 5 pounds per ton of acid produced at sulfur-burning plants, and about 1 to 10 pounds per ton at spent acid plants.

Control Systems - SO_2 emissions can be controlled by use of a dual absorption process, sodium sulfite scrubbing, lime/limestone solution scrubbing, ammonia solution scrubbing, or molecular sieves. Dual absorption and ammonia scrubbing are the more popular control methods. In the dual absorption process, SO_2 emissions are decreased by increasing the SO_2-to-SO_3 conversion efficiency. The SO_3 formed in the initial converter stages is removed in a primary absorber, and the remainder of the gas is returned to the converter. The additional SO_3 formed is absorbed in a secondary absorber. The dual absorption configuration can reduce SO_2 emissions to a range of about 1 to 4 pounds per ton of acid produced. However, for acid plants treating smelter gas, the range may be greater due to SO_2 concentration variations.

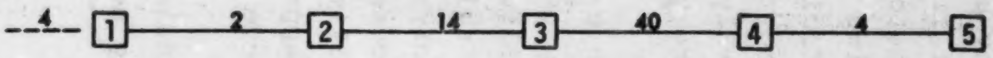
Sodium sulfite or ammonia scrubbing of absorber off-gas can reduce SO_2 emissions to between 1.5 and 4 pounds per ton of acid. The recovered SO_2 is normally recycled to the acid plant. Either process can reduce SO_2 emissions to approximately 100 ppm. Spent ammonia scrubbing liquor is either used to produce ammonium sulfate or thermally decomposed to recycle SO_2 to the acid plant. A multistage scrubber and a high-efficiency particulate collection device are normally required to minimize ammonia losses and to prevent formation of a visible plume caused by ammonium salts.

Molecular sieve separation is capable of reducing SO_2 emissions to between 50 and 100 ppm. The recovered SO_2 is recycled to the acid plant.

Acid mist emissions are usually controlled by use of electrostatic precipitators or various designs of fiber type mist eliminators. Tubular fiber type mist eliminators are frequently used for plants producing oleum or using virgin nonsulfur feedstocks because their collection efficiency is slightly higher than the horizontal dual fiber pad type or vertical fiber panel type mist eliminator. Properly selected, a fiber type mist eliminator can operate with zero visible emissions.

Compliance Schedules - Figure 3-33 illustrates an expeditious schedule for modifying an existing plant to use the dual absorption process. Figures 3-34 and 3-35 illustrate expeditious schedules for installation of sodium sulfite and ammonium solution scrubbing processes, respectively; the schedule for the ammonium solution scrubbing process incorporates the time required for simultaneous installation of a high-efficiency particulate control device. An approximate time schedule for installation of a molecular sieve separation process is shown in Figure 3-36.

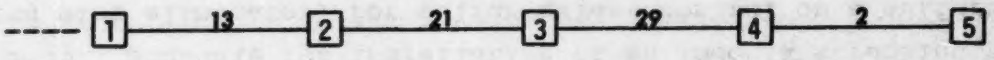
Figure 3-37 illustrates an expeditious schedule for installation of a mist eliminator for controlling acid mist emissions.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	70
5	Date by which final compliance is achieved.	74

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

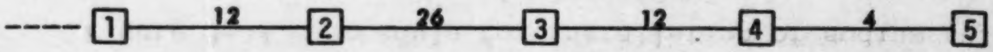
Figure 3-33. Schedule for modifying a sulfuric acid plant to the dual absorption process.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	
2	Date of award of control device contract.	13
3	Date of initiation of on-site construction or installation of emission control equipment.	34
4	Date by which on-site construction or installation of emission control equipment is completed.	63
5	Date by which final compliance is achieved.	65

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

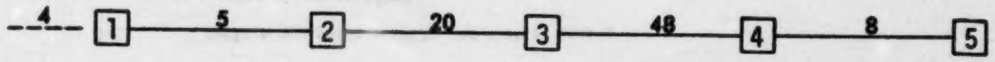
Figure 3-34. Schedule for installation of sodium sulfite scrubbing system on a sulfuric acid plant.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	50
5	Date by which final compliance is achieved.	54

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

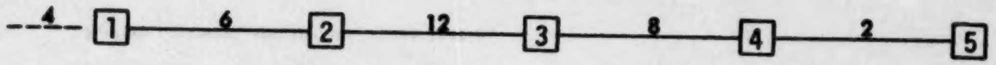
Figure 3-35. Schedule for installation of an ammonia scrubbing system, including mist eliminator, for sulfur oxides control on a sulfuric acid plant.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	9
3	Date of initiation of on-site construction or installation of emission control equipment.	29
4	Date by which on-site construction or installation of emission control equipment is completed.	77
5	Date by which final compliance is achieved.	85

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-36. Tentative schedule for installation of a molecular sieve separation process for sulfur oxides control on a sulfuric acid plant.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	22
4	Date by which on-site construction or installation of emission control equipment is completed.	30*
5	Date by which final compliance is achieved.	32

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

* 52 weeks if booster blower required.

Figure 3-37. Schedule for installation of a mist eliminator for acid mist control on a sulfuric acid plant.

Sources of Additional Information

Source	Type of information*
1. Engineering Analysis of Emissions Control Technology for Sulfuric Acid Manufacturing Processes. Prepared by Chemical Construction Corp. for U.S. Public Health Service, Cincinnati, Ohio. NTIS No. PB 190-393. March 1970. 337 p.	P, E, C
2. Background Information for Proposed New-Source Performance Standards: Steam Generators, Incinerators, Portland Cement Plants, Nitric Acid Plants, and Sulfuric Acid Plants. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. PB 202-459. August 1971. 50 p.	P, E, C
3. Atmospheric Emissions from Sulfuric Acid Manufacturing Processes. Public Health Service, Cincinnati, Ohio. Publication No. AP-13. 1965. 136 p.	P, E, C
4. Duecker, W.W. and J.J. West. Manufacture of Sulfuric Acid. A.C.S. Mono. 144. Reinhold Publishing Co., New York. 1959.	P
5. Air Pollution Aspects of Emission Sources: Sulfuric Acid Manufacturing. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. PB 200-079. May 1971. 64 p.	E, C

*P = Process description
E = Emission rates
C = Control devices

3.4.4 Paint and Varnish

Process Description - The manufacture of paint involves dispersing a colored oil or pigment into a vehicle that can be applied to a surface, usually a resin or oil, and adding either a hydrocarbon solvent or water to lower the viscosity of the paint for ease of application. Only physical processes are involved; no chemical reactions take place. Figure 3-38 presents a simple flow diagram of a paint mixing process.

The manufacture of varnish also involves the mixing and blending of various ingredients. In this process, however, chemical reactions are initiated by cooking the varnish in open or closed gas-fired kettles for 4 to 16 hours at temperatures between 200 and 650°F.

Atmospheric Emissions - Particulates can be emitted from the handling of dry pigments. The quantities vary with the care taken in handling and with the method of transferring the dry materials. Typical emission values range from 0.5 to 1.0 percent of the pigment handled.

Emissions of hydrocarbons, the pollutants of primary concern, are due to the use of organic solvents. Depending on the cooking time and temperature, type of solvent, and type of enclosure, hydrocarbon emissions from varnish cooking range from 20 to 160 pounds per ton of product. The corresponding hydrocarbon emission rate for paint manufacture is approximately 30 pounds per ton of paint produced.

Control Systems - Catalytic oxidation and direct-flame incineration are used to control hydrocarbon emissions from paint and varnish plants. With catalytic units, the collected process off-gases and vapors are heated by combustion of fuel to approximately 600 to 800°F. They are then passed through the catalyst bed, where oxidation of the hydrocarbons

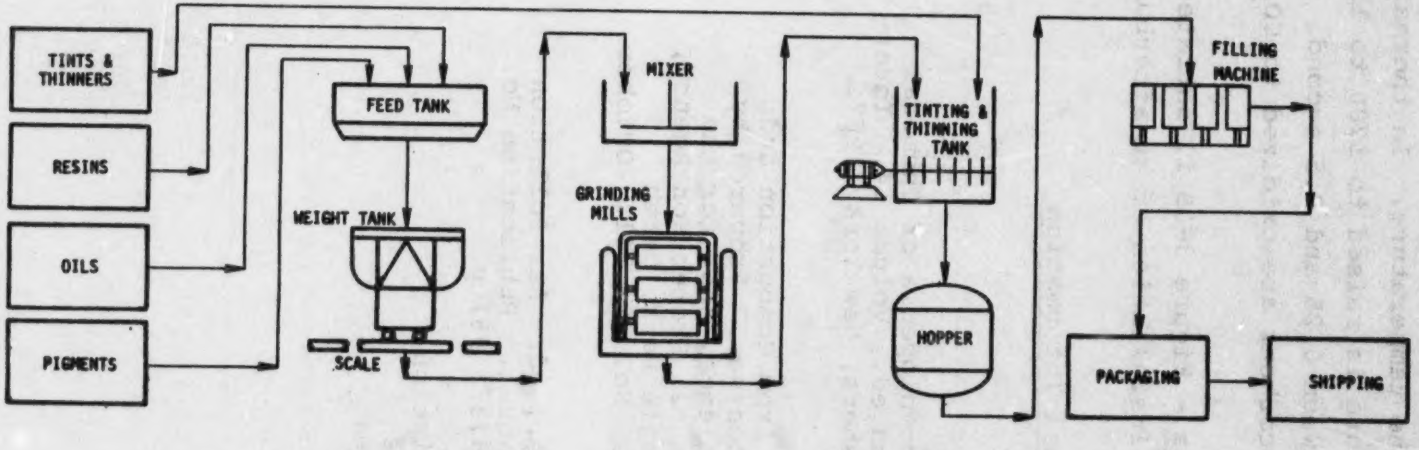

TINTS & THINNERS
RESINS
OILS
PIGMENTS
FEED TANK
WEIGHT TANK
SCALE
MIXER
GRINDING MILLS
TINTING & THINNING TANK
HOPPER
FILLING MACHINE
PACKAGING
SHIPPING

Figure 3-38. Paint mixing process.

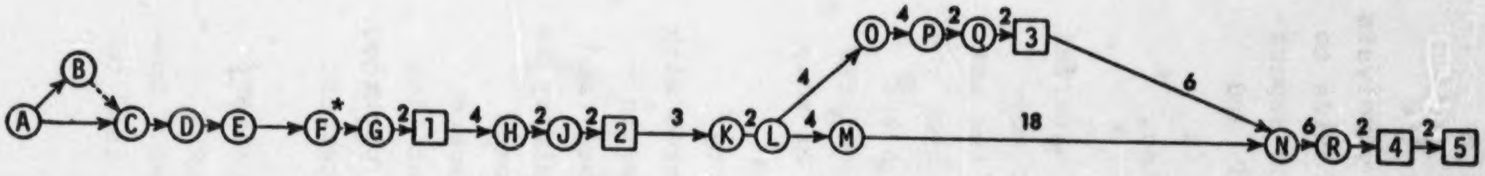
further increases the temperature. In thermal incineration units, the temperature is raised to 1200 to 1500°F for residence times between 0.25 and 0.5 second. In both types of units, the hydrocarbons are oxidized to CO_2 and water vapor.

Compliance Schedules - Figure 3-39 illustrates an expeditious schedule for installation of an afterburner.

Sources of Additional Information

	Source	Type of information*
1.	Kirk-Othmer Encyclopedia of Chemical Technology, 2nd ed., Volume 14. Interscience Publishers, New York, 1967. p. 462-485.	P, C
2.	Exhaust Gases from Combustion and Industrial Processes. Prepared by Engineering-Science, Inc. for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. 204 861. October 1971. 440 p.	E
3.	Danielson, J.A., ed. Air Pollution Engineering Manual. Publication No. AP-40. May 1973. 987 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	27
4	Date by which on-site construction or installation of emission control equipment is completed.	45
5	Date by which final compliance is achieved.	47

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-39. Schedule for installation of an afterburner for hydrocarbon control on paint or varnish operations.

3.4.5 Soap and Detergents

Process Description - Present commercial methods for the manufacture of soap consist primarily of catalytic hydrolysis of various fatty acids with sodium or potassium hydroxide to form a glycerol-soap mixture. This mixture undergoes separation through distillation, followed by neutralization and blending to produce different grades of soap. Soap is finished in many forms, such as bars, flakes, granules, liquids, and powders.

In the manufacture of soap in powder form, the material is spray dried. Prior to spray drying, additives to complete the formulation are suspended or dissolved in the hot soap and the mixture is then pumped through nozzles near the top of a spray tower. Circulation of hot air through the tower evaporates water from the spray, forming the powdered soap. A schematic flow diagram for the manufacture of soap is shown in Figure 3-40.

In the manufacture of synthetic detergents, fatty alcohols or linear alkylate compounds are first treated with sulfuric acid. The sulfonated compounds are then neutralized with caustic solution, and various dyes, perfumes, and other compounds are added. The resulting paste or slurry is pumped to the top of a drying tower and sprayed through nozzles to form small droplets. As the droplets descend, the moisture content is reduced by the countercurrent flow of hot air. The dried detergent is then cooled and packaged. A simplified flow diagram for the manufacture of detergent granules is shown in Figure 3-41.

Atmospheric Emissions - Odors are the emissions of primary concern from soap manufacture. The severity of odorous emissions depends upon the type of feed material used. Low-grade stocks obtained from rendered grease and fats tend to

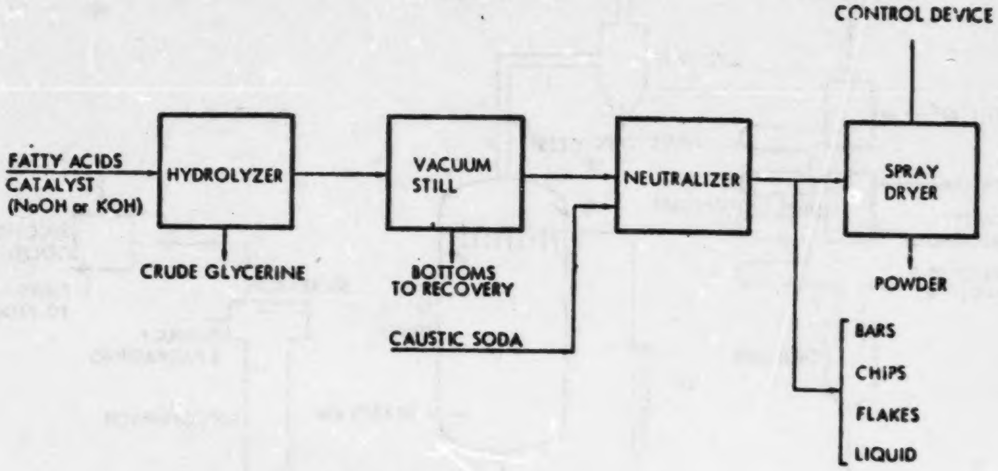

CONTROL DEVICE
FATTY ACIDS
CATALYST
(NaOH or KOH)
HYDROLYZER
VACUUM STILL
NEUTRALIZER
SPRAY DRYER
CRUDE GLYCERINE
BOTTOMS TO RECOVERY
CAUSTIC SODA
POWDER
BARS
CHIPS
FLAKES
LIQUID

Figure 3-40. Soap manufacture.

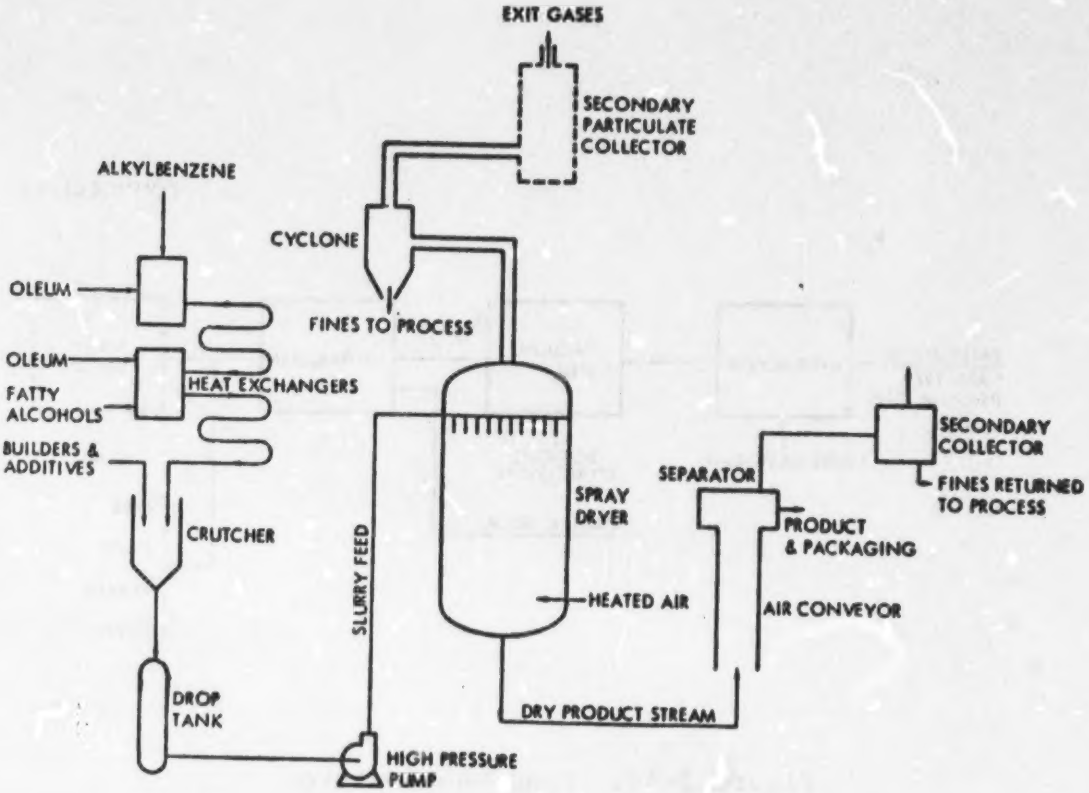

EXIT GASES
SECONDARY PARTICULATE COLLECTOR
ALKYLBENZENE
CYCLONE
OLEUM
FINES TO PROCESS
OLEUM
FATTY ALCOHOLS
HEAT EXCHANGERS
BUILDERS & ADDITIVES
CRUTCHER
SLURRY FEED
SPRAY DRYER
SEPARATOR
SECONDARY COLLECTOR
FINES RETURNED TO PROCESS
PRODUCT & PACKAGING
HEATED AIR
AIR CONVEYOR
DROP TANK
DRY PRODUCT STREAM
HIGH PRESSURE PUMP

Figure 3-41. Detergent manufacture.

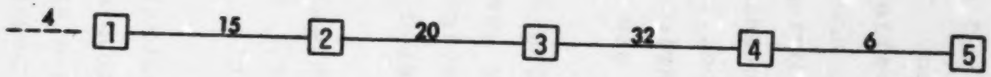
be odoriferous. Local dust emissions can also occur during blending, mixing, and packaging of the finished soap. Uncontrolled spray dryers can be a major source of particulate emissions.

Emissions from synthetic detergent manufacture can be classified as those resulting from preparation of the synthetic feed compounds from petrochemical stock and those resulting from the final detergent-making operation. The former are essentially hydrocarbons emitted from relief valves, from storage vessels, and from atmospheric and vacuum fractionation operations. The latter come primarily from the spray drier. Uncontrolled particulate emissions from the spray drier are approximately 90 pounds per ton of product. Particulates can also be emitted from various handling and packaging operations, although these are usually controlled because of the product's value.

Control Systems - Emissions of particulate and odors from the spray drying of soap or detergent are commonly controlled by a wet scrubber followed by an electrostatic precipitator, if necessary. The stack gases are sometimes reheated to prevent formation of a visible plume.

Dust from blending, mixing, and packaging operations can be controlled by collection in a fabric filter. Hydrocarbon emissions from relief valves and fractionation towers can be controlled by incineration.

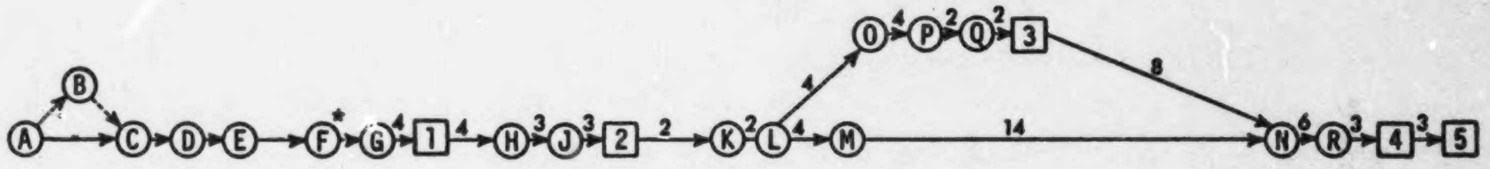
Compliance Schedules - Figures 3-42 and 3-43 illustrate, respectively, expeditious schedules for installation of a wet scrubber/electrostatic precipitator system on a spray drying tower and a fabric filter on blending and packaging operations.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	39
4	Date by which on-site construction or installation of emission control equipment is completed.	71
5	Date by which final compliance is achieved.	77

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-42. Schedule for installation of a wet scrubber electrostatic precipitator for particulate control on a spray drying tower.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	47
5	Date by which final compliance is achieved.	50

Activity designation	Activity description
A-B	Conduct source tests
A-C	Perform preliminary investigation
C-D	Evaluate control alternatives
D-E	Commit funds for total program
E-F	Prepare control plan and compliance schedule for agency
F-G	Agency reviews and approves plans
G-1	Finalize plans and specifications
1-H	Procure control device bids
H-J	Evaluate control device bids
J-2	Award control device contract
2-K	Prepare assembly drawings

Activity designation	Activity description
K-L	Review and approve assembly drawings
L-M	Prepare fabrication drawings
M-N	Fabricate control device
L-O	Prepare engineering drawings
O-P	Procure construction bids
P-Q	Evaluate construction bids
Q-3	Award construction contract
3-N	Initiate on-site construction
N-R	Install control device
R-4	Complete construction and system tie-in
4-5	Perform startup, shakedown, and emission testing

Figure 3-43. Schedule for installation of fabric filter for particulate control on blending and packaging operations.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., ed. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, E, C
2.	Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition. Volume 18. Interscience Publishers, New York, 1967.	P

*P = Process description
E = Emission rates
C = Control devices

3.4.6 Chlorine Manufacture by the Mercury Cell Process

Process Description - Approximately 30 percent of all manufactured chlorine is produced electrolytically by the mercury cell process. The balance is produced by the diaphragm cell process.

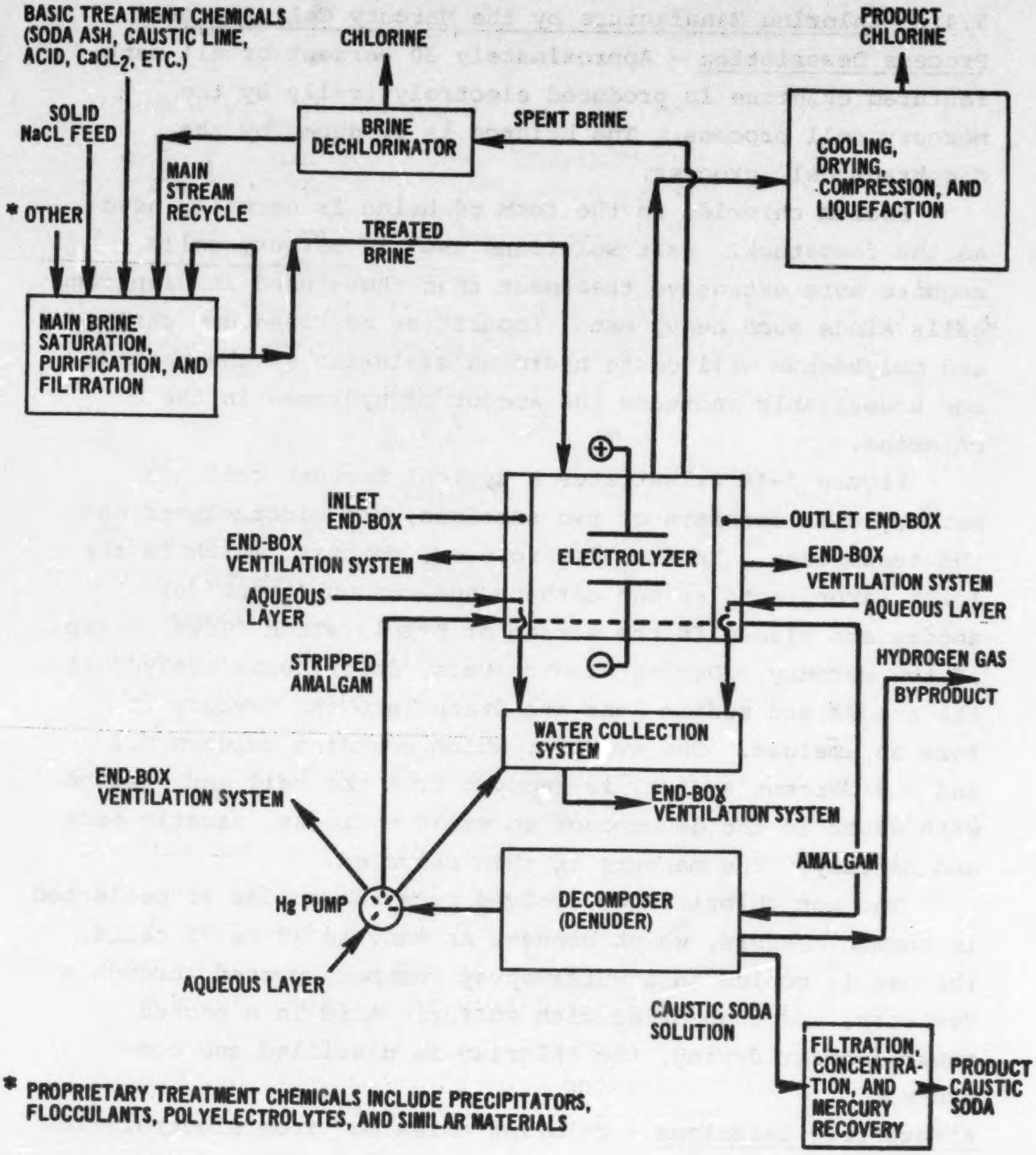
Sodium chloride in the form of brine is normally used as the feedstock. Salt solutions used in mercury cells require more extensive treatment than those used in diaphragm cells since such heavy metal impurities as vanadium, chromium, and molybdenum will cause hydrogen evolution at the cathode and undesirably increase the amount of hydrogen in the chlorine.

Figure 3-44 illustrates a typical mercury cell. A mercury cell consists of two sections, the electrolyzer and the decomposer. In the electrolyzer, mercury, which is the lower layer, acts as the cathode and carbon (graphite) anodes are placed in the stream of brine, which flows on top of the mercury. During electrolysis, chlorine is evolved at the anodes and sodium ions are drawn into the mercury to form an amalgam. The amalgam, which contains between 0.1 and 0.3 percent sodium, is removed from the cell and reacted with water in the decomposer to yield hydrogen, caustic soda and mercury. The mercury is then recycled.

The hot chlorine gas evolved from the anodes is collected in common headers, which connect as many as 70 to 75 cells. The gas is cooled in a water spray chamber, passed through a demister, and then dried with sulfuric acid in a packed tower. After drying, the chlorine is distilled and compressed.

Atmospheric Emissions - Chlorine emissions from electrolytic chlor-alkali plants can occur from:

1. Cell operation


BASIC TREATMENT CHEMICALS (SODA ASH, CAUSTIC LIME, ACID, $CaCl_2$, ETC.)
CHLORINE
PRODUCT CHLORINE
SOLID NaCL FEED
BRINE DECHLORINATOR
SPENT BRINE
MAIN STREAM RECYCLE
COOLING, DRYING, COMPRESSION, AND LIQUEFACTION
* OTHER
TREATED BRINE
MAIN BRINE SATURATION, PURIFICATION, AND FILTRATION
+
INLET END-BOX
OUTLET END-BOX
END-BOX VENTILATION SYSTEM
ELECTROLYZER
END-BOX VENTILATION SYSTEM
AQUEOUS LAYER
AQUEOUS LAYER
−
STRIPPED AMALGAM
HYDROGEN GAS BYPRODUCT
WATER COLLECTION SYSTEM
END-BOX VENTILATION SYSTEM
END-BOX VENTILATION SYSTEM
AMALGAM
Hg PUMP
DECOMPOSER (DENUDER)
AQUEOUS LAYER
CAUSTIC SODA SOLUTION
FILTRATION, CONCENTRATION, AND MERCURY RECOVERY
PRODUCT CAUSTIC SODA

* PROPRIETARY TREATMENT CHEMICALS INCLUDE PRECIPITATORS, FLOCCULANTS, POLYELECTROLYTES, AND SIMILAR MATERIALS

Figure 3-44. Chlor-alkali mercury-cell operation.

2. Acidifying, air blowing, and vacuum treating of the depleted brine.

3. The chlorine liquefaction process (as "blow gas").

4. Losses through vents from storage tanks, process transfer tanks, tank cars, and shipping containers.

5. Leaks or spills due to corrosion, wear, and accidents.

Quantitative emission data are not available.

Emissions of mercury to the atmosphere occur from:

1. The hydrogen by-product stream.

2. The end-box ventilation system.

3. The cell room ventilation air.

The hydrogen by-product stream leaving the decomposer is saturated with mercury vapor (1.0 grain of mercury vapor per cubic foot at 210°F). Cooling the hydrogen stream to 110°F, along with partial mist elimination reduces emissions to about 50 pounds for each 100 tons of chlorine produced.

Mercury emissions from an untreated or inadequately treated end-box ventilation system range from 2 to 15 pounds for each 100 tons of chlorine produced.

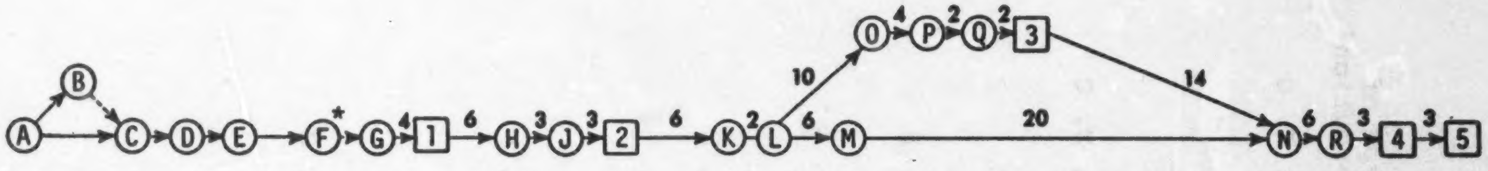
The volumetric flow rate of the cell room ventilation stream ranges from 100,000 to 1,000,000 cubic feet per minute for each 100 tons of daily chlorine capacity. A higher flow of air may be needed in old plants, where mercury concentrations are more likely to be high. On the basis of data obtained from operating plants, it is estimated that mercury emissions from the cell room ventilation system range from 0.5 to 5.0 pounds per day per 100 tons of daily chlorine capacity.

__Control System__ - Wet caustic scrubbers are the preferred method of collecting chlorine gas released from acidulating of the depleted brine. The chlorine from the cells is collected in packed towers with sulfuric acid.

Mercury emissions can be eliminated by switching to the diaphragm cell process. This change, however, requires a major modification of the brine handling systems.

Since mercury is very volatile, emissions can be reduced by cooling the exit gas streams, either with direct contact scrubbers or with refrigeration systems using brine. Adsorption on impregnated activated carbon or molecular sieves also will reduce emissions.

__Compliance Schedule__ - Figure 3-45 illustrates the compliance schedule for installation of high-energy venturi scrubbers. This system would reduce both chlorine and mercury emissions by absorption and cooling, respectively. Wastewater would be treated and recycled. The schedule shows an overall time period of 68 weeks, exclusive of installation of a wastewater treatment facility. The on-site construction period, which is the longest single interval on this schedule, is required to accomodate the installation of corrosion-resistant piping, pumps, ducts, and controls.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	42
4	Date by which on-site construction or installation of emission control equipment is completed.	65
5	Date by which final compliance is achieved.	68

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-45. Schedule for installation of a high-energy venturi scrubber on chlor-alkali plant.

Sources of Additional Information

Source	Type of information*
1. Control Techniques for Chlorine and Hydrogen Chloride Emissions. Prepared by PEDCo Environmental for the U.S. Environmental Protection Agency under Contract No. CDA-70-96. March 1971.	P, E, C
2. Engineering Guide for Processing OEPA Air Pollution Permits. Industrial Pollution Section, OEPA Division of Waste Management and Engineering. July 1973.	P, E, C
3. Compilation of Air Pollution Emission Factors, 2nd ed. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. pp. 5-5 to 5-6.	E
4. Atmospheric Emissions from Chlor-Alkali Manufacture. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-80. January 1971. 116 p.	P, E
5. Stahl, Q.R. Preliminary Air Pollution Survey of Chlorine Gas. U.S. Environmental Protection Agency, Raleigh, North Carolina. Publication No. APTD 69-33. October 1969. pp. 25-35.	P, E
6. Control Techniques for Mercury Emissions from Extraction and Chlor-Alkali Plants. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-118. February 1973. pp. 3-19 to 3-33.	E, C

*P = Process description
E = Emission rates
C = Control devices

3.4.7 Carbon Black Industry

Process Description - The carbon black industry processes hydrocarbon feedstocks (mainly heavy oils) into finely divided carbon black particles for use largely in manufacture of tires, and to a lesser extent, pigments, cement, and cosmetics. Carbon black products are distinguished by the particle size of the unagglomerated particles, ranging from 5 to 500 millimicrons. Most carbon black plants produce 25 to 75 thousand tons per year of product.[1]

Carbon black is made by three processes - the furnace, thermal, and channel processes. The channel process is being phased out, and only one plant is in operation. The furnace process currently accounts for about 90 percent of production, and the thermal process for the remaining 10 percent.[2] A flow sheet for the furnace process is presented in Figure 3-46.

The furnace process basically involves the incomplete combustion and thermal cracking of a liquid hydrocarbon feedstock under controlled conditions in a reactor at a temperature of approximately 2550°F to produce a finely divided carbon particulate.[2] The gaseous effluent from the reactor is quenched with water to approximately 1000°F to stop the cracking reactions and then is further cooled to about 450°F.[2] The particulate (raw carbon black) is then removed from the gas stream by passage through a fabric filter system. A number of reactors are normally connected by a manifold and served by a single quench chamber and product collection system.

In the thermal process, decomposition of a natural gas is produced by thermal cracking at a temperature of 2400 to 2800°F in the absence of air to yield carbon and hydrogen.[2] The product stream is then filtered to remove carbon black

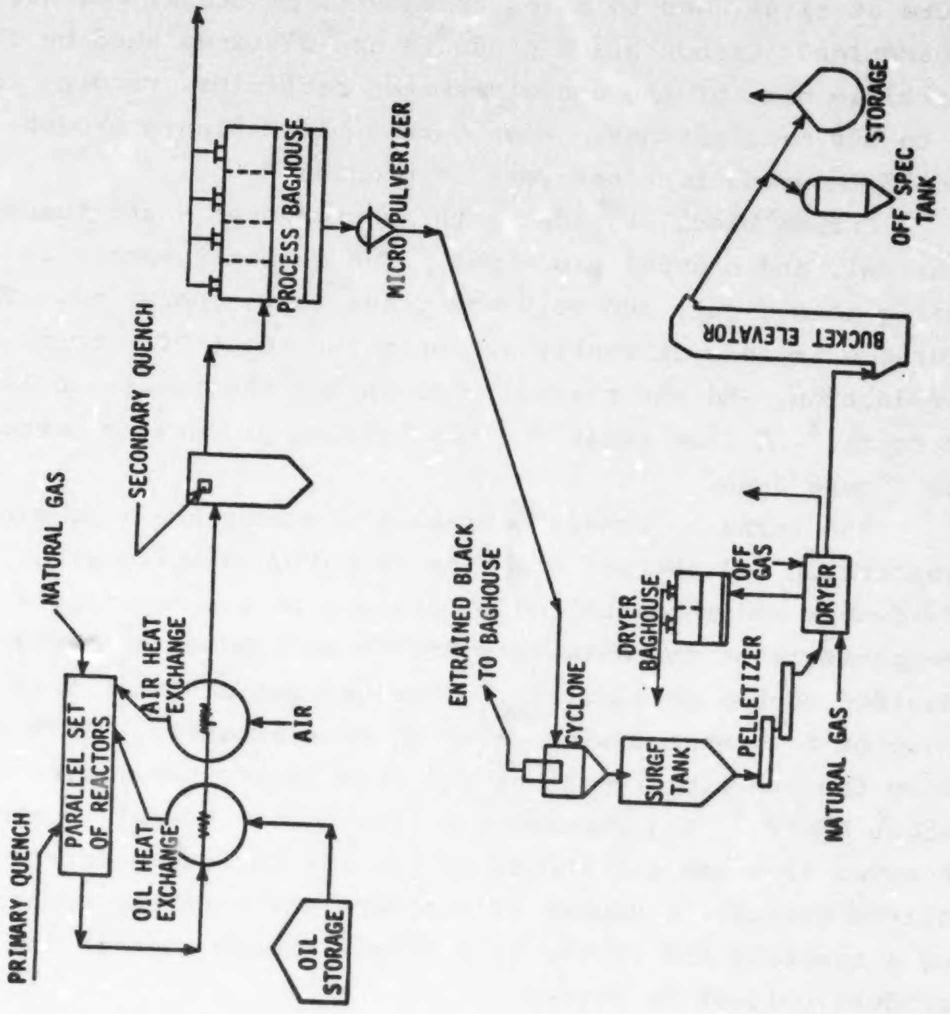

PRIMARY QUENCH
PARALLEL SET OF REACTORS
NATURAL GAS
OIL HEAT EXCHANGE
AIR HEAT EXCHANGE
AIR
OIL STORAGE
SECONDARY QUENCH
PROCESS BAGHOUSE
MICRO PULVERIZER
ENTRAINED BLACK TO BAGHOUSE
CYCLONE
SURGE TANK
DRYER BAGHOUSE
OFF GAS
DRYER
PELLETIZER
NATURAL GAS
BUCKET ELEVATOR
OFF SPEC TANK
STORAGE

Figure 3-46. Typical furnace carbon black process.[1]

and the exit gas is burned to generate heat for additional cracking.

Raw carbon black leaving the filtration step is pulverized by a micropulverizer to break up any agglomerates, pelletized to facilitate handling, and finally dried in a rotary drum dryer prior to storage and shipment.

Atmospheric Emissions - Atmospheric emissions of carbon monoxide, gaseous and condensible hydrocarbons, particulate, and hydrogen sulfide are the primary pollutants associated with carbon black manufacture; these pollutants are generated by the high-temperature cracking of the hydrocarbon feedstocks.

At thermal process plants the off-gases are recycled to the reactor, and emissions rates are very low. Some particulate emissions occur when the reactors are switched from the cracking to the heating cycle. At furnace process plants, however, CO emissions are roughly 100 percent of product weight. Hydrocarbon emissions from the furnace process consist of methane and acetylene; these are largely nonreactive in photochemical processes. Emissions of H_2S are directly related to sulfur content of the feed, amounting to approximately 0.01 times the percent sulfur in the feed on a weight basis. Emissions of NO_x are very low because of lack of air in the reactor. Particulate emissions depend mainly on product size and process fabric filter efficiency.[1]

The purge gas from the dryer contains particulate. Average emission rate is 0.08 pound per ton of product after the product recovery filter.[1]

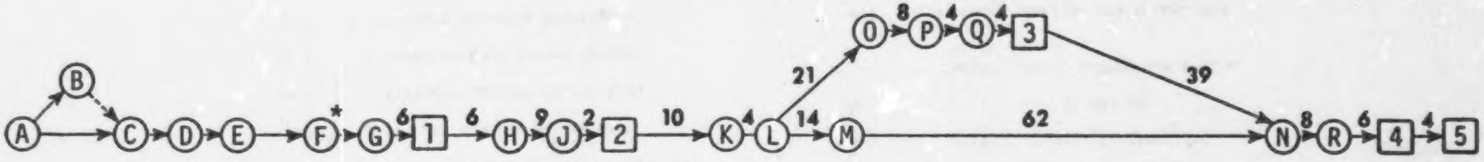
Control Systems - Control of particulate from the furnace and thermal processes is generally very good. Poor control results in product loss and low yield. Fabric filter systems are widely used to ensure high collection efficiency

(99+ percent). These filters function both as process equipment and emission controls. Some companies use cyclones ahead of the filter to improve the removal efficiency of the fabric filter.

Cyclones, scrubbers, and fabric filters are used to control exhausts of the dryer purge gas stream. If a scrubber is used, the liquid effluent is used in the pelletizer and no liquid waste occurs.

The CO in the furnace off-gas stream can be controlled by off-gas incineration or use of a CO boiler. Although there is limited use for steam at carbon black plants, some furnace process plants combust the off-gas and export steam. Others use incineration without heat recovery to reduce odors from H_2S emissions. To obtain CO removal efficiencies of greater than 95 percent, firebox temperatures should range from 1400 to 1600°F with residence times of about 0.4 second.[1]

Compliance Schedule - Figures 3-47 and 3-48 show expeditious schedules for installation of a field-erected and a packaged CO boiler, respectively. Installation time for a field-erected unit is 131 weeks, whereas installation of a package CO boiler requires approximately 68 weeks. These schedules include control device fabrication times of 62 and 23 weeks for the field-erected and packaged CO boiler, respectively.



* Refer to Chapter 2 for time increments A to G.

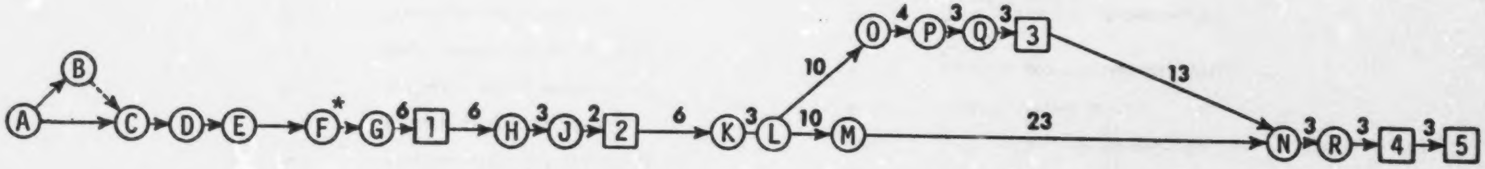
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	23
3	Date of initiation of on-site construction or installation of emission control equipment.	74
4	Date by which on-site construction or installation of emission control equipment is completed.	127
5	Date by which final compliance is achieved.	131

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-47. Schedule for installation of a field-erected CO boiler.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	17
3	Date of initiation of on-site construction or installation of emission control equipment.	46
4	Date by which on-site construction or installation of emission control equipment is completed.	65
5	Date by which final compliance is achieved.	68

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-48. Schedule for installation of a packaged CO boiler.

Sources of Additional Information

	Source	Type of information*
1.	Background Information - Best Systems of Emission Reduction for Furnace Type Carbon Black Plants. Prepared by PEDCo Environmental Specialists, Inc. for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Contract No. 68-02-1321. Task No. 9. December 1975. 209 p.	P, E, C
2.	Gerstle, R.W. Carbon Black Industry. Environmental Catalog of Industrial Processes. Prepared by PEDCo Environmental Specialists, Inc. for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Contract No. 68-02-1321. Task No. 21. May 1975. 25 p.	P, E, C
3.	Schwartz, W.A., et al. Engineering and Cost Study of Air Pollution for the Petrochemical Industry. Volume I: Carbon Black Manufacture by the Furnace Process, Houdry Division, Air Products. Environmental Protection Agency, Raleigh, North Carolina. Publication No. EPA-450/3-73-006a. June 1974. 127 pp.	P, E, C
4.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. pp. 5.13-1 and 5.13-2.	E
5.	Cheremisinoff, P.N. and R.A. Young. Pollution Engineering Practice Handbook. Ann Arbor Science Publishers, Inc. Ann Arbor, Michigan. 1975. pp. 177-180.	C

6.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. pp. 704-711.	P, E, C

*P - Process description
E - Emission rates
C - Control devices

3.4.8 Ammonium Nitrate

Process Description - Ammonium nitrate is made by neutralizing nitric acid with ammonia gas. The neutralization is generally carried out in a batch reaction according to the reaction:

$$NH_3(g) + HNO_3(l) \rightarrow NH_4NO_3(l)$$

Figure 3-49 illustrates the commercial production of ammonium nitrate prills.

In this process the ratio of ammonia and acid is automatically controlled. The heat of neutralization evaporates a part of the water and gives a solution of 83 percent ammonium nitrate. Final evaporation to above 99 percent is accomplished in a falling film evaporator. The resultant melt flows through spray nozzles and downward through a prill tower countercurrent to ambient air. The melt is cooled and solidified to form round pellets or prills.

The prills are continually removed from the bottom of the tower and fed to a rotary cooler. Fines from the cooler are typically collected in a wet cyclone and returned to the neutralizer. After cooling, the prills are screened to size; the over- and undersize prills are sent to a sump and returned to the neutralizer. Intermediate or product-size prills are dusted with a coating material, usually diatomaceous earth, in a rotary coating drum and sent to a bagging operation.

Atmospheric Emissions - Emissions of particulate and ammonia from the top of the prill tower constitute the major atmospheric emissions. This discharge air contains from 0.1 to 0.3 percent ammonium nitrate, most of which is under 0.5 micron diameter, as shown below:

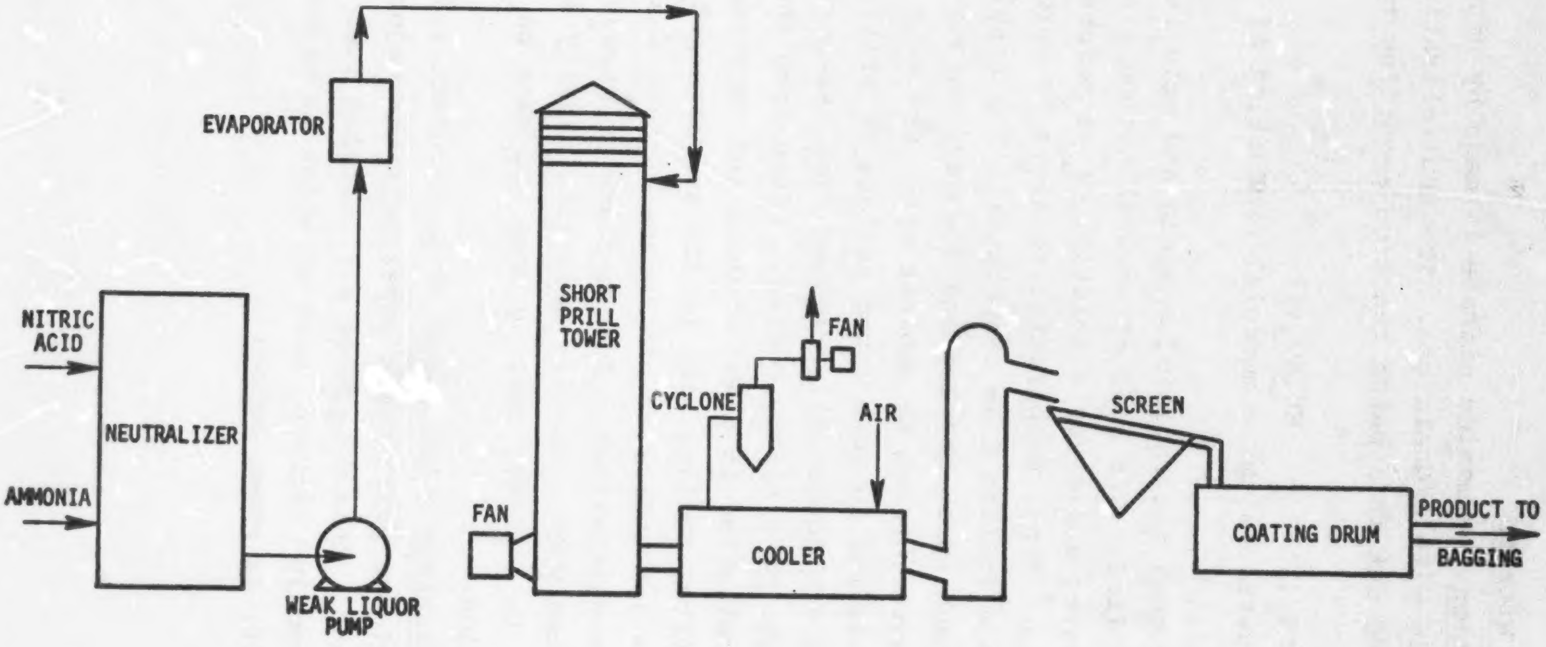

NITRIC ACID
AMMONIA
NEUTRALIZER
WEAK LIQUOR PUMP
EVAPORATOR
FAN
SHORT PRILL TOWER
CYCLONE
FAN
AIR
COOLER
SCREEN
COATING DRUM
PRODUCT TO BAGGING

Figure 3-49. Ammonium nitrate manufacturing process.

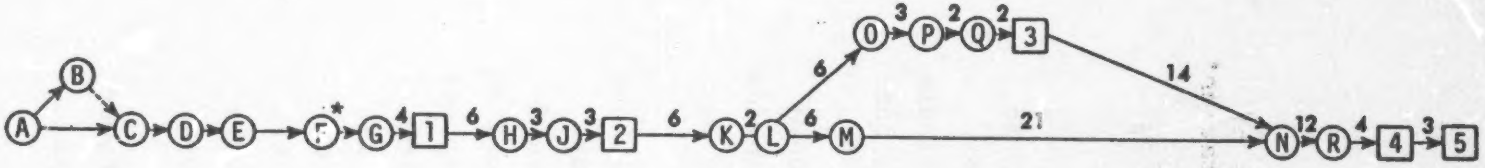
Particle size, microns	Test No. 1 %	Test No. 2 %
<0.3	0	0
0.3-0.5	39	74
0.5-1	54	20
1-2	7	6
>2	0	0

The grain loading in these tests ranged from 0.07 to 0.26 grain per cubic foot at 65,000 scfm and 120°F. Plume opacity was approximately 60 percent.

Control Systems - Exhaust air is drawn through a shroud in the top of the prill tower and sent to a high-energy wet scrubber and mist eliminator. The captured ammonium nitrate is recycled. Emissions of ammonium nitrate and ammonia can reportedly be reduced to 1.0 and 0.15 pound per ton of product, respectively. Another control system for ammonia nitrate prill towers utilizes a spray scrubber system inside the prill tower and recirculates the scrubbing solution to the neutralizer.

Compliance Schedule - Figure 3-50 illustrates an expeditious schedule for installing a shroud, wet scrubber, and mist eliminator on an ammonium nitrate prill tower. This schedule shows an overall time period of 68 weeks, which could be reduced by a few weeks if on-site construction and equipment activity could be further expedited. This control system requires a high-pressure fan, which, together with the fan motor, is a long-delivery item. The scrubber must be constructed of corrosion-resistant material, either stainless steel or glass-reinforced plastic. Because such scrubbers are built only to order, delivery time is somewhat longer than normal.

The spray scrubber system installed in the prill tower requires an overall time period of 30 to 45 weeks. This



* Refer to Chapter 2 for time increments A to G.

☐ Milestones
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	35
4	Date by which on-site construction or installation of emission control equipment is completed.	65
5	Date by which final compliance is achieved.	68

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-50. Schedule for installation of a shroud, wet scrubber, and mist eliminator on an ammonium nitrate prill tower.

installation proceeds more quickly because the system requires no large fans and ductwork.

Sources of Additional Information

	Source	Type of information*
1.	Shreve, R. The Chemical Process Industries, 2nd edition. McGraw-Hill, New York. 1956. 1004 p.	P

*P = Process description

3.4.9 Urea Manufacturing Process

Process Description - Urea is synthesized by reacting ammonia (NH_3) with carbon dioxide (CO_2) at approximately 4500 psig and 390°F to form ammonium carbamate, and simultaneously dehydrating the ammonium carbamate to urea, as shown in Figure 3-51. The following equations show the chemical reations:

$$2\ NH_3 + CO_2 \rightarrow NH_2\ COONH_4 \text{ (Ammonium carbamate)}$$

$$NH_2\ COONH_4 \rightarrow NH_2\ CONH_2 + H_2O \text{ (Urea)}$$

The urea synthesis reactor always contains unreacted carbamate and excess ammonia, depending upon the composition of the feeds. This material is removed from the urea solution and reused. Depending on how the unreacted material is reused, the commercial urea synthesis processes are grouped into the following main categories:

- Once-through urea process
- Solution recycle urea process
- Internal carbamate recycle urea process.

Product urea normally obtained from the synthesis section as a 70 to 90 weight percent aqueous solution is usually further processed to solid urea by evaporation or by crystallization with crystal remelt. In both cases the product is molten pure urea. The molten urea is sprayed and solidified into small spherical particles (prills) in a prill tower as shown in Figure 3-52.

Atmospheric Emissions - Carryover from the urea prill tower ranges from 0.04 to 0.22 grain per cubic foot with an updraft velocity of 1200 feet per minute. Measurements at one plant showed the following particle size distribution:

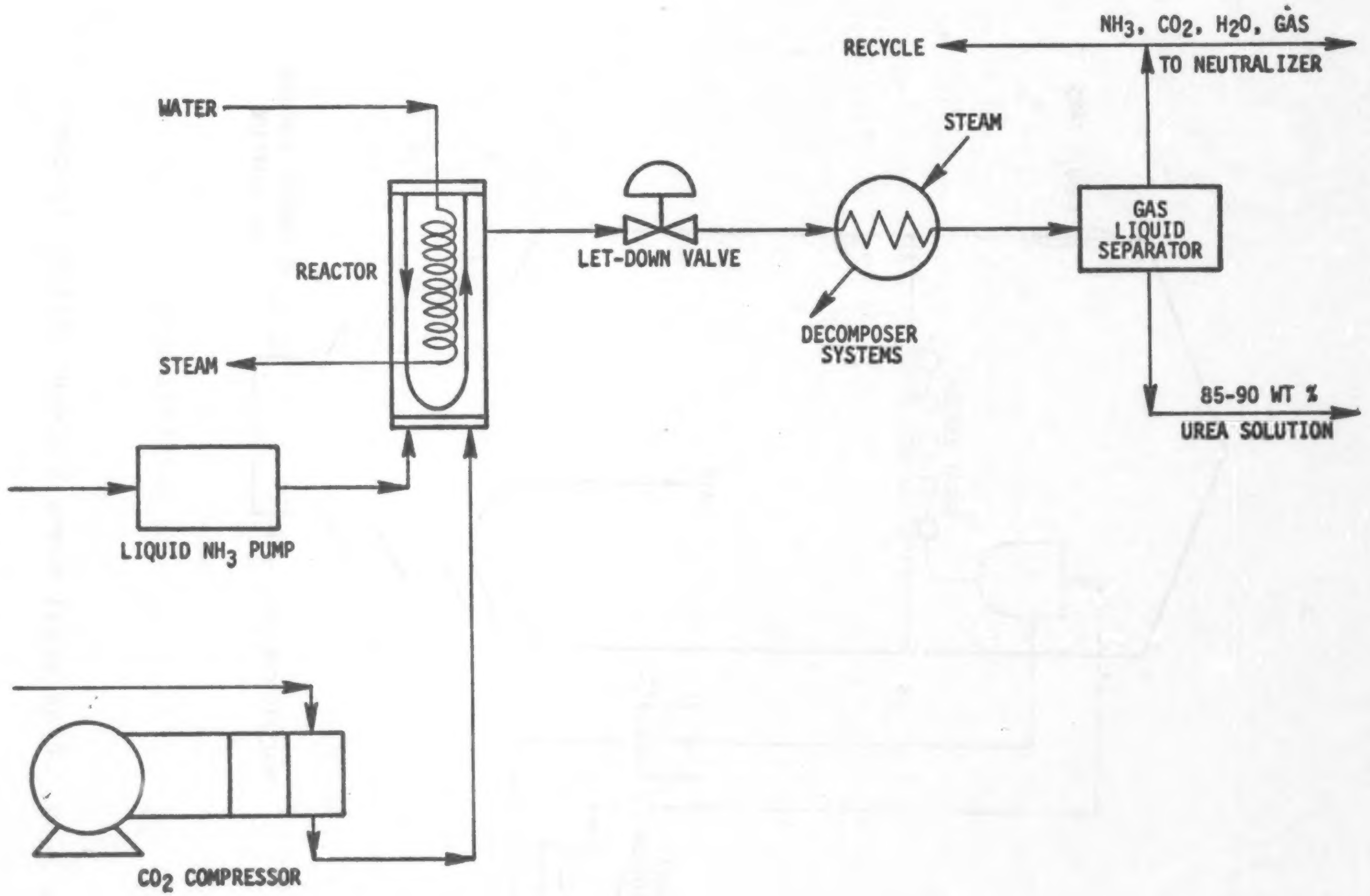

RECYCLE
NH_3, CO_2, H_2O, GAS
TO NEUTRALIZER
WATER
STEAM
REACTOR
LET-DOWN VALVE
STEAM
DECOMPOSER SYSTEMS
GAS LIQUID SEPARATOR
85-90 WT %
UREA SOLUTION
STEAM
LIQUID NH_3 PUMP
CO_2 COMPRESSOR

Figure 3-51. Urea manufacturing process.

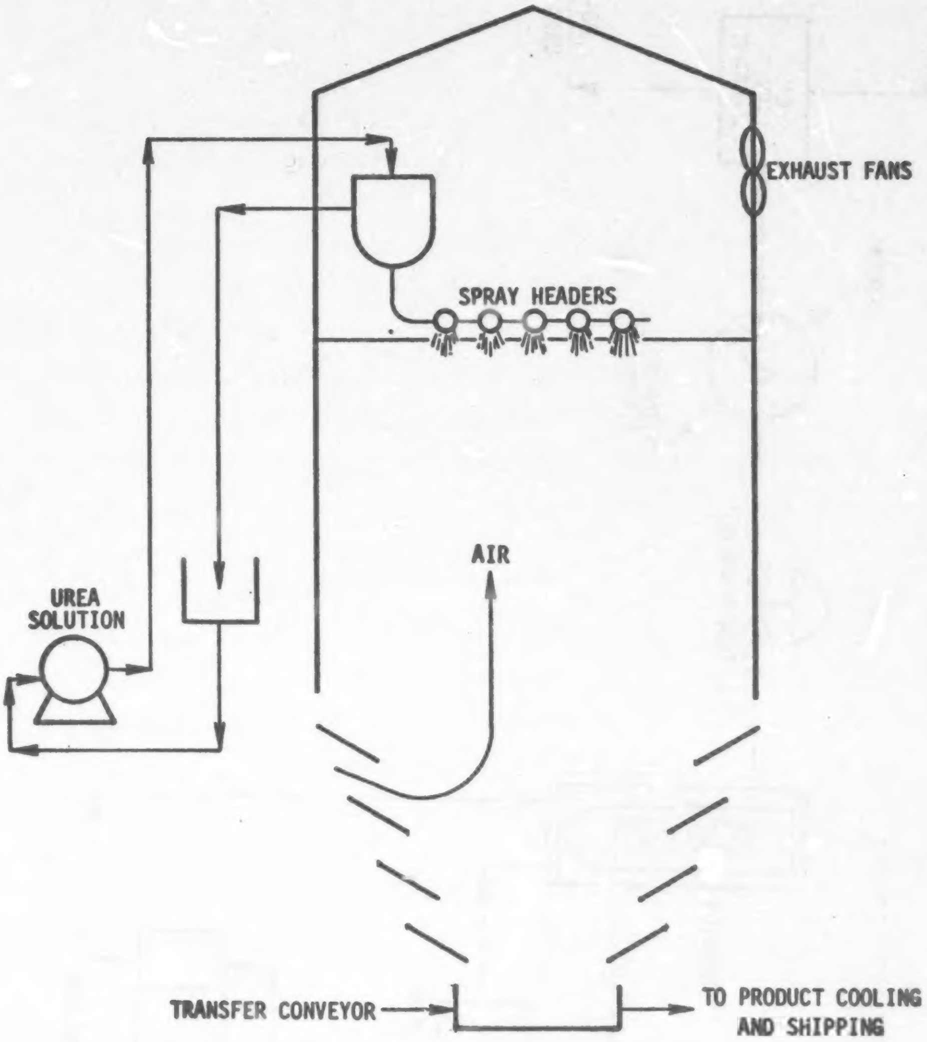

EXHAUST FANS
SPRAY HEADERS
AIR
UREA SOLUTION
TRANSFER CONVEYOR
TO PRODUCT COOLING AND SHIPPING

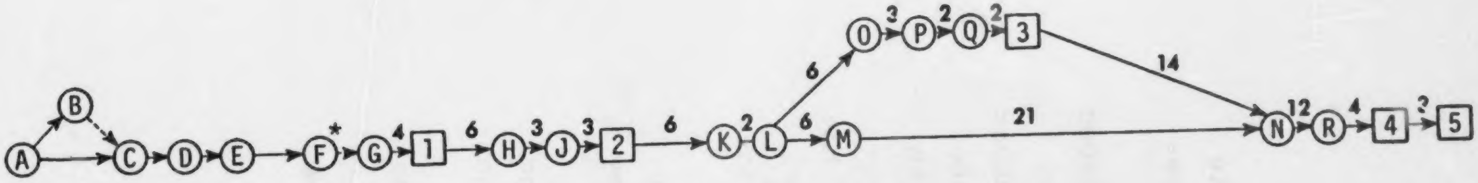
Figure 3-52. - Urea prill tower without control system.

Particle size, microns	% by weight
0 - 2.5	44.8
2.5 - 5	16.6
5 - 10	17.2
>10	21.4

Because of the high percentage of fines, a highly visible plume was produced. Upward air flow through the tower was 80,000 scfm.

Control Systems - To capture particulate emissions, a shroud is placed around the spray to sieve section in the top of the tower. The exhaust air is then ducted to a wet scrubber followed by vane-type mist eliminators, passes through the fan, and is discharged to the atmosphere. Some towers are equipped with refrigerant coolers, and the air is recirculated up the tower. The scrubbing liquor is recycled to the process.

Compliance Schedule - Figure 3-53 illustrates an expeditious schedule for installing a shroud, wet scrubber, and mist eliminator on a urea prill tower. This schedule shows an overall time period of 68 weeks, which could be reduced by a few weeks if on-site construction and equipment activity could be further expedited. One long-delivery item is the high-pressure fan and motor. Because the scrubber must be built to order of corrosion-resistant material, either stainless steel or glass-reinforced plastic, delivery time is longer than normal.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	35
4	Date by which on-site construction or installation of emission control equipment is completed.	65
5	Date by which final compliance is achieved.	68

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-53. Schedule for installation of a shroud, wet scrubber, and mist eliminator on a urea prill tower.

Source of Additional Information

	Source	Type of information*
1.	Shreve, R. Norris. The Chemical Process Industries, 2nd edition. McGraw-Hill, New York, 1956. 1004 p.	P
2.	Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition. Volume 21. Interscience Publishers, New York. 1967. p. 37-56.	P

*P = Process description

3.4.10 Plastics

Process Description - Plastics manufacturing generally consists of polymerizing an organic compound, drying it, and finally treating and forming the plastic product. Polymerization is mostly done in an indirectly heated reaction vessel that is jacketed and lined with glass or stainless steel. The vessel is normally completely enclosed; it is equipped with a stirring mechanism and may contain a reflux condenser. The reactants required to form plastic resins differ for various plastics. For example, polyester resins are formed by the condensation reaction between a polyhydric alcohol and a polybasic acid. Polyvinyl resins are generally produced by polymerization of vinyl acetate and vinyl chloride.

After the polymerization reaction is complete, the resin is separated from unwanted products of reaction, washed, and dried. Compounding (addition to the polymer of such ingredients as stabilizers, colorants, plasticizers, and flame retardants) is done after drying. The specific additives depend on the end use of the plastic. Compounding may be done by a two-roll mill, an extruder, or a mixer.

After compounding, the plastics may be dried and crushed if they are used for molding or they may be thinned with solvent and stored if the plastic is used for protective coating. Sometimes the polymers are stored in latex form as they come from the reaction vessel. Figure 3-54 shows a simplified flow diagram of typical plastics manufacturing.

Atmospheric Emissions - Major emissions from this industry are raw materials or monomers, solvents or other volatile liquids emitted during the reaction, sublimed solids such as phtalic anhydride emitted in alkyd production, and solvents

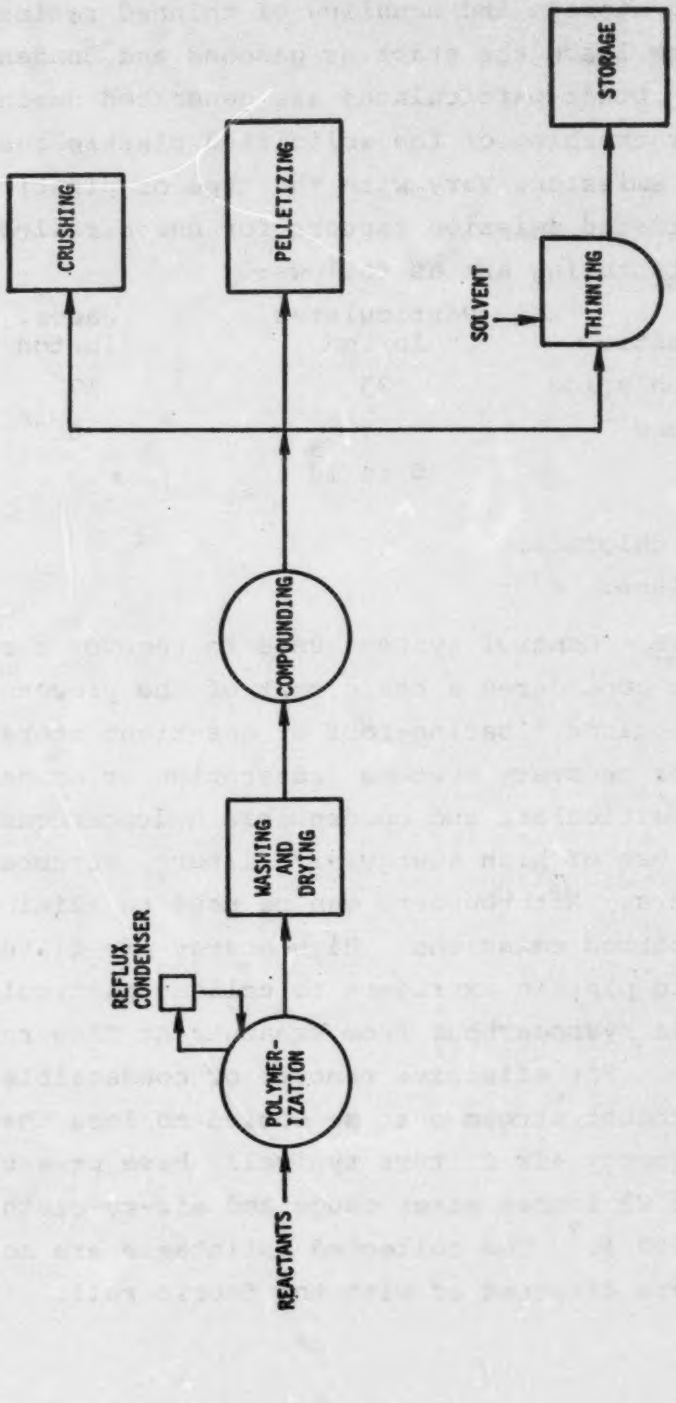

REACTANTS
POLYMER-IZATION
REFLUX CONDENSER
WASHING AND DRYING
COMPOUNDING
CRUSHING
PELLETIZING
SOLVENT
THINNING
STORAGE

Figure 3-54. Simplified plastics manufacturing process.

emitted during storage and handling of thinned resins. These emissions leave the stack as gaseous and condensed hydrocarbons. Other particulates are generated during pelletizing or crushing of the solidified plastic resin. Quantities of emissions vary with the type of plastic product. Estimated emission factors for uncontrolled plastics manufacturing are as follows:[1]

Type of plastic	Particulates, lb/ton	Gases, lb/ton
Polyvinyl chloride	35	17[a]
Polypropylene	3	0.7[b]
General	5 to 10	

[a] As vinyl chloride.

[b] As propylene.

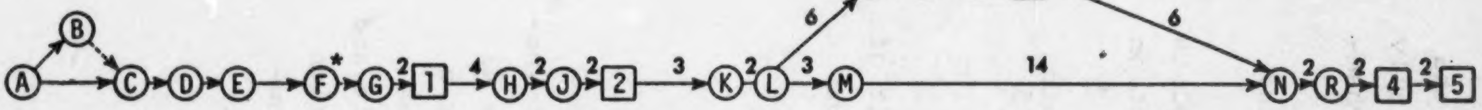
Control Systems - Control systems used to recover a reactant or product are considered a basic part of the process equipment. These include floating-roof or gas-tight storage tanks and vapor recovery systems (adsorption or condensation).[2] Emissions of particulate and condensible hydrocarbons can be controlled by use of high energy air filters, scrubbers, or mist eliminators. Afterburners can be used to eliminate gaseous hydrocarbon emissions. High-energy air filters have been applied to plastic extruders to collect particulates and condensible hydrocarbons from exhausts at flow rates up to 60,000 acfm. For effective removal of condensible hydrocarbons the exhaust stream must be cooled to less than 150°F. High-energy air filters typically have pressure drops of about 28 inches water gauge and air-to-cloth ratios of 500/1 to 1500/1.[3] The collected pollutants are not recycled but are disposed of with the fabric roll.

Various types of scrubbers can be used to control the plastics process. One type is a settling chamber partially filled with water followed by water sprays.[4] A spray chamber precleaner followed by a venturi scrubber is also effective.[4] These scrubbers will not collect significant amounts of gaseous hydrocarbons.

Fiber-bed mist eliminators remove plasticizer droplets by trapping them in a bed of fibers. For proper collection efficiency with this device, the gas inlet temperature should be a maximum of 90 to 120°F. The collected liquid can be disposed of or used for plasticizer reclamation.[5]

Afterburners are used to incinerate hydrocarbons from plastics manufacturing. The exhaust must be heated to temperatures often exceeding 1500°F to reduce 90 percent of the organics to carbon dioxide and water. This technique should not be used when the plasticizers contain such elements as phospherous, sulfur, chlorine, and nitrogen, since the products of combustion can be worse than the organics.[5]

Compliance Schedules - Figures 3-55 through 3-58 show expeditious schedules for installing a high-energy air filter, a typical low-pressure wet scrubber, a mist eliminator, and an afterburner. Installation times range from 41 weeks for a high-energy air filter unit to 50 weeks for a mist eliminator. Fabrication requires the greatest time increment in all cases. The high-energy air filter unit and afterburner require approximately 14 weeks for fabrication and the fabrication duration for mist eliminator and low-energy scrubber is about 15 and 20 weeks, respectively.



* Refer to Chapter 2 for time increments A to G.

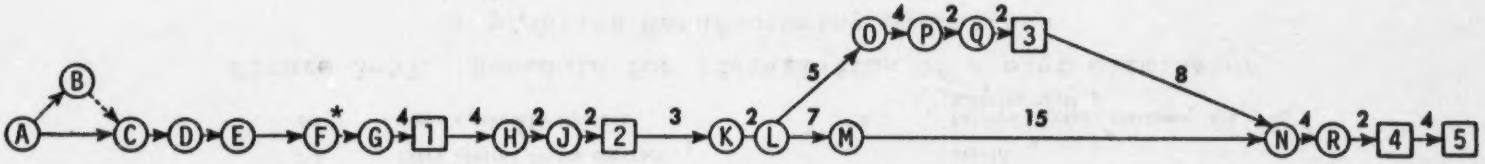
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	29
4	Date by which on-site construction or installation of emission control equipment is completed.	39
5	Date by which final compliance is achieved.	41

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-55. Schedule for installation of a high-energy air filter unit on plastics manufacturing operations.



* Refer to Chapter 2 for time increments A to G.

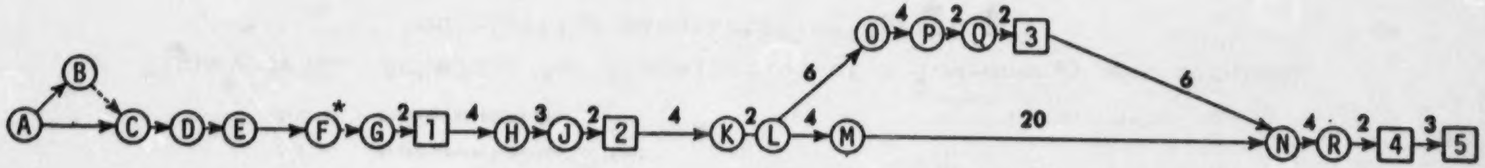
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	45
5	Date by which final compliance is achieved.	49

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-56. Schedule for installation of a low-energy wet scrubber on plastics manufacturing operations.



* Refer to Chapter 2 for time increments A to G.

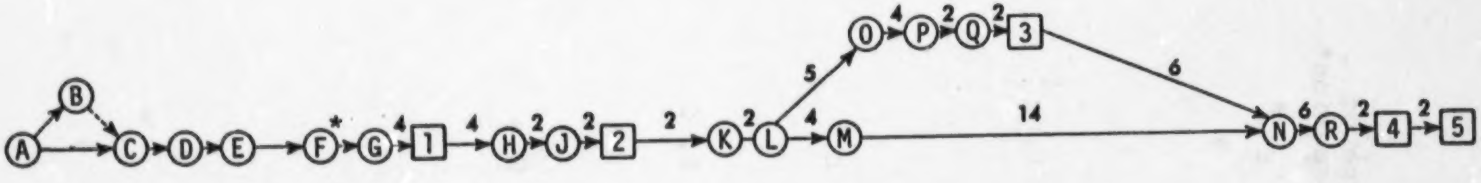
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	11
3	Date of initiation of on-site construction or installation of emission control equipment.	31
4	Date by which on-site construction or installation of emission control equipment is completed.	47
5	Date by which final compliance is achieved.	50

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-M	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-57. Schedule for installation of a mist eliminator on plastics manufacturing operations.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	29
4	Date by which on-site construction or installation of emission control equipment is completed.	44
5	Date by which final compliance is achieved.	46

Activity designation	Activity description
A-B	Conduct source tests
A-C	Perform preliminary investigation
C-D	Evaluate control alternatives
D-E	Commit funds for total program
E-F	Prepare control plen and compliance schedule for agency
F-G	Agency reviews and approves plans
G-1	Finalize plans and specifications
1-H	Procure control device bids
H-J	Evaluate control device bids
J-2	Award control device contract
2-K	Prepare assembly drawings

Activity designation	Activity description
K-L	Review and approve assembly drawings
L-M	Prepare fabrication drawings
M-N	Fabricate control device
L-O	Prepare engineering drawings
O-P	Procure construction bids
P-Q	Evaluate construction bids
Q-3	Award construction contract
3-N	Initiate on-site construction
N-R	Install control device
R-4	Complete construction and system tie-in
4-5	Perform startup, shakedown, and emission testing

Figure 3-58. Schedule for installation of an afterburner on plastics manufacturing operations.

Sources of Additional Information

	Source	Type of information*
1.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. pp. 5.13-1 and 5.13-2.	E
2.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. pp. 704-711.	P, E, C
3.	HEAF/CHEAF Brochure and Installation List. Bulletins 112 5/75 and 113 5/75. Anderson 2000, Inc. Atlanta, Georgia. May 1975.	C
4.	Engineering Guide for Processing OEPA Air Pollution Permits. Ohio Environmental Protection Agency, Columbus, Ohio. July 1973. pp. 5-14-1 to 5-14-13.	P, E, C
5.	Cheremisinoff, P.N. and R.A. Young. Pollution Engineering Practice Handbook. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan. 1975. pp. 177-180.	C

*P = Process description
E = Emission rates
C = Control devices

3.5 AGRICULTURAL PRODUCTS

3.5.1 Grain Handling and Processing

Process Description - Grain handling and processing encompass a variety of operations from the initial receipt of the grain at either a country or terminal elevator to the delivery of such finished products as flour, livestock feed, soybean oil, and corn syrup. Primary operations in this industry include: (1) grain handling and transferring; (2) milling of dry corn, wet corn, soybeans, rice, durum, and wheat; and (3) feed manufacturing.

Grain is handled and transferred at country and terminal elevators. Country elevators receive grain from farms by truck for future delivery to terminal elevators. At a typical terminal elevator, the grain is unloaded, cleaned, dried, stored, turned periodically, and eventually shipped to another elevator or processed at an adjacent facility. Figure 3-59 illustrates the basic operations of a terminal elevator.

Milling of dry and wet corn, soybeans, rice, durum, and wheat involves several steps: (1) grain receiving; (2) cleaning and drying; (3) grinding or milling; (4) sifting, separating, and mixing; and (5) final loading of the finished products and by-products. Unloading and loading operations are similar to those of a terminal elevator. The by-products of the milling industries are frequently shipped to feed mills for further processing. Figures 3-60, 3-61, and 3-62 illustrate general operations for soybean processing, flour milling, and wet corn milling. Grain drying is discussed in Section 3.2.

Processing of grains into mixed feed involves grinding the grain, mixing it with the other ingredients of the formula, and forming the feed into the desired shape and

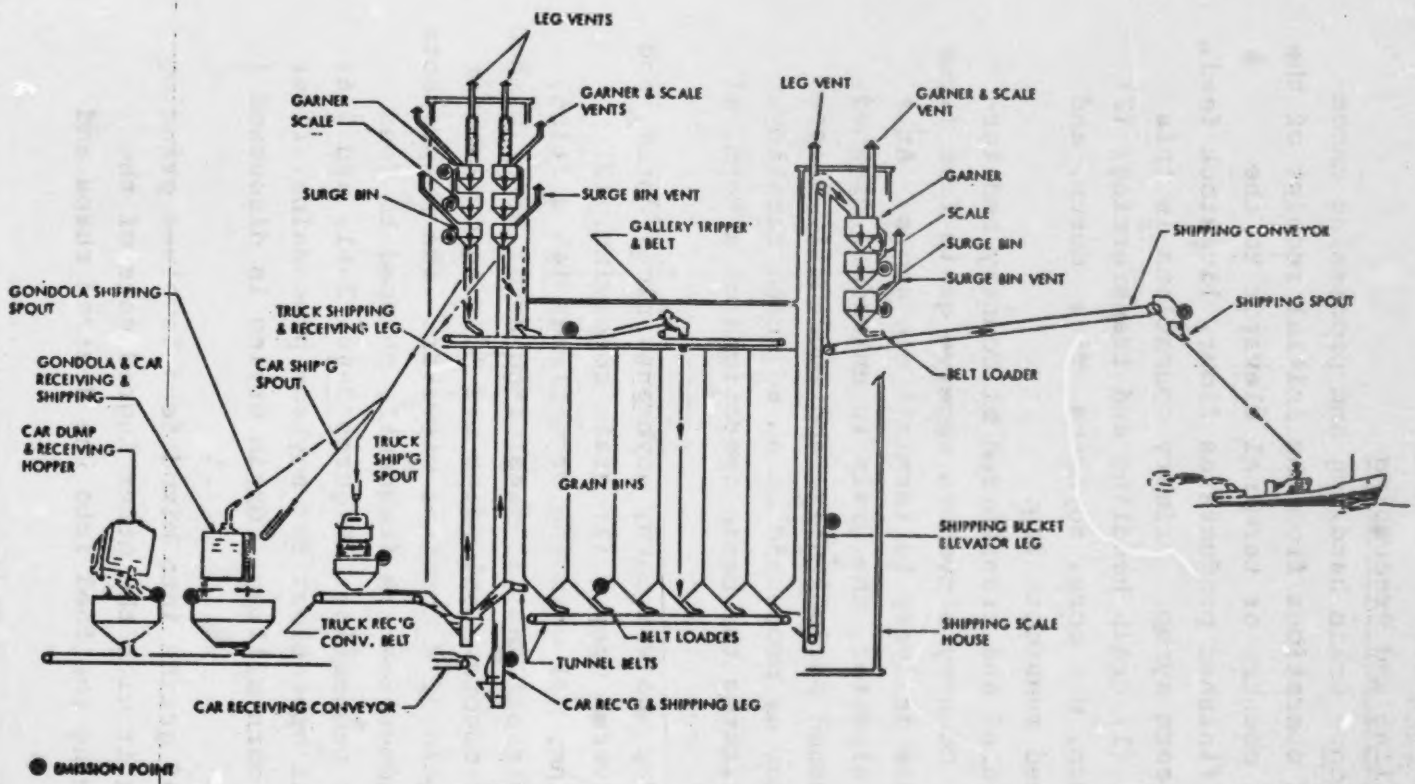

LEG VENTS
GARNER
SCALE
GARNER & SCALE VENTS
SURGE BIN
SURGE BIN VENT
GALLERY TRIPPER & BELT
GONDOLA SHIPPING SPOUT
TRUCK SHIPPING & RECEIVING LEG
GONDOLA & CAR RECEIVING & SHIPPING
CAR SHIP'G SPOUT
CAR DUMP & RECEIVING HOPPER
TRUCK SHIP'G SPOUT
GRAIN BINS
TRUCK REC'G CONV. BELT
BELT LOADERS
TUNNEL BELTS
CAR RECEIVING CONVEYOR
CAR REC'G & SHIPPING LEG
EMISSION POINT
LEG VENT
GARNER & SCALE VENT
GARNER
SCALE
SURGE BIN
SURGE BIN VENT
SHIPPING CONVEYOR
SHIPPING SPOUT
BELT LOADER
SHIPPING BUCKET ELEVATOR LEG
SHIPPING SCALE HOUSE

Figure 3-59. Terminal grain elevator.

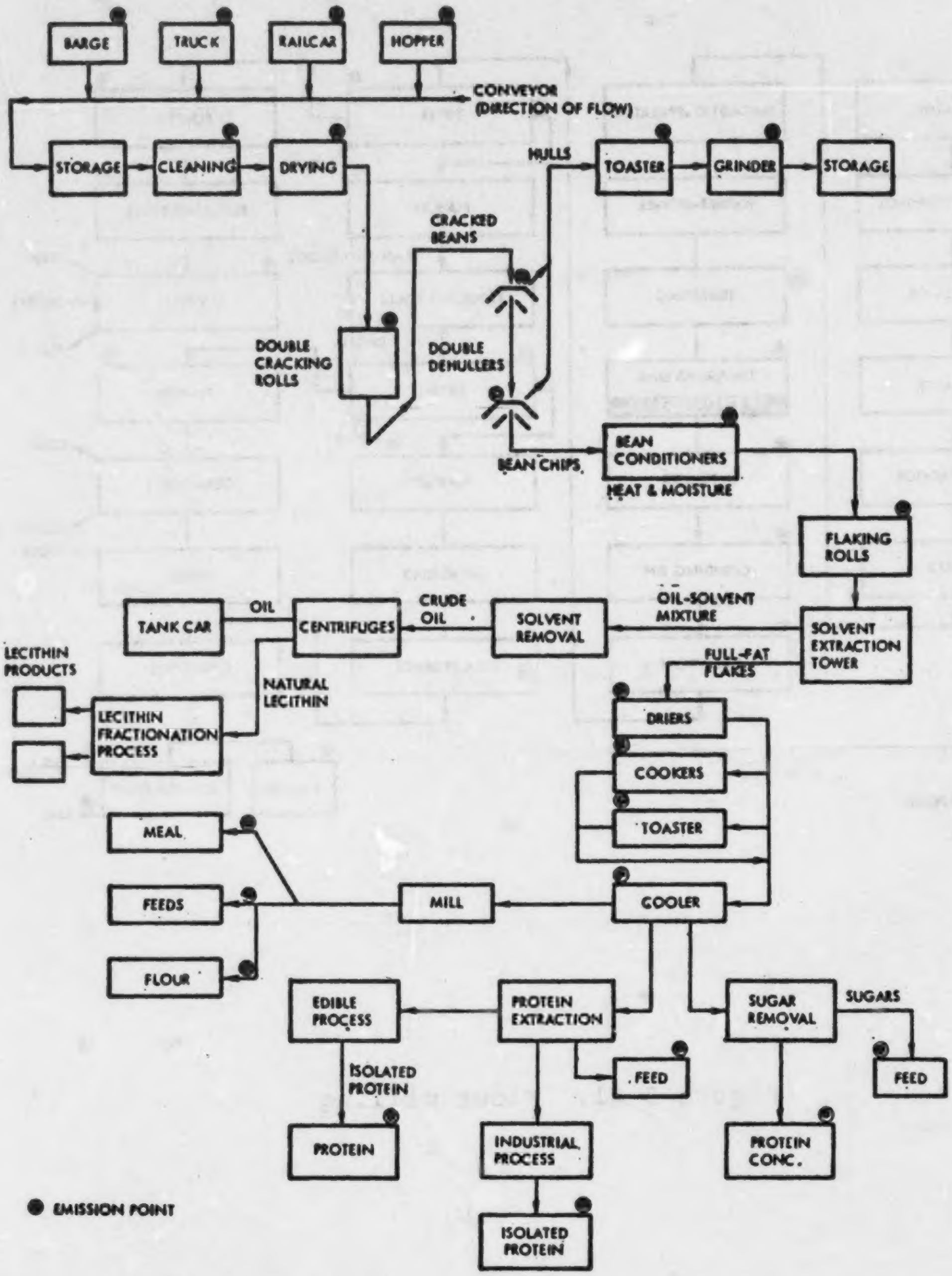

BARGE
TRUCK
RAILCAR
HOPPER
CONVEYOR (DIRECTION OF FLOW)
STORAGE
CLEANING
DRYING
HULLS
TOASTER
GRINDER
STORAGE
CRACKED BEANS
DOUBLE CRACKING ROLLS
DOUBLE DEHULLERS
BEAN CHIPS
BEAN CONDITIONERS
HEAT & MOISTURE
FLAKING ROLLS
TANK CAR
OIL
CENTRIFUGES
CRUDE OIL
SOLVENT REMOVAL
OIL-SOLVENT MIXTURE
SOLVENT EXTRACTION TOWER
FULL-FAT FLAKES
LECITHIN PRODUCTS
LECITHIN FRACTIONATION PROCESS
NATURAL LECITHIN
DRIERS
COOKERS
TOASTER
MEAL
FEEDS
FLOUR
MILL
COOLER
EDIBLE PROCESS
PROTEIN EXTRACTION
SUGAR REMOVAL
SUGARS
FEED
FEED
ISOLATED PROTEIN
PROTEIN
INDUSTRIAL PROCESS
PROTEIN CONC.
ISOLATED PROTEIN
● EMISSION POINT

Figure 3-60. Soybean processing.

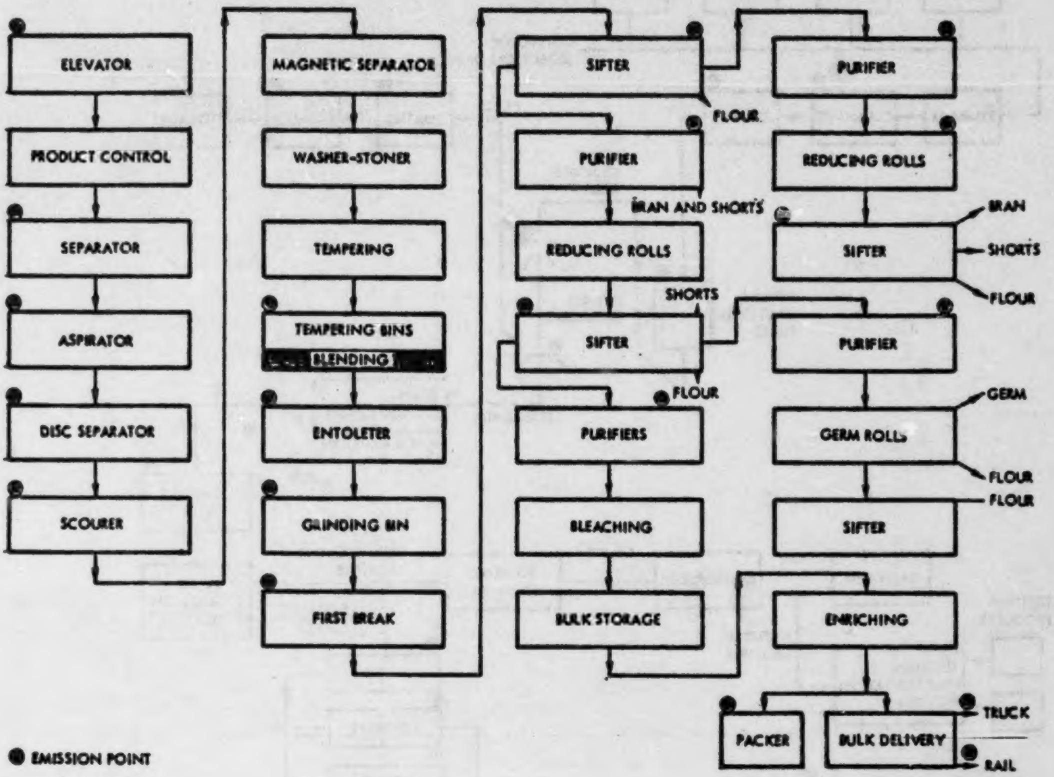

ELEVATOR
PRODUCT CONTROL
SEPARATOR
ASPIRATOR
DISC SEPARATOR
SCOURER
MAGNETIC SEPARATOR
WASHER-STONER
TEMPERING
TEMPERING BINS
BLENDING
ENTOLETER
GRINDING BIN
FIRST BREAK
SIFTER
FLOUR
PURIFIER
BRAN AND SHORTS
REDUCING ROLLS
SHORTS
SIFTER
FLOUR
PURIFIERS
BLEACHING
BULK STORAGE
PURIFIER
REDUCING ROLLS
SIFTER
BRAN
SHORTS
FLOUR
PURIFIER
GERM
GERM ROLLS
FLOUR
FLOUR
SIFTER
ENRICHING
PACKER
BULK DELIVERY
TRUCK
RAIL
EMISSION POINT

Figure 3-61. Flour milling.

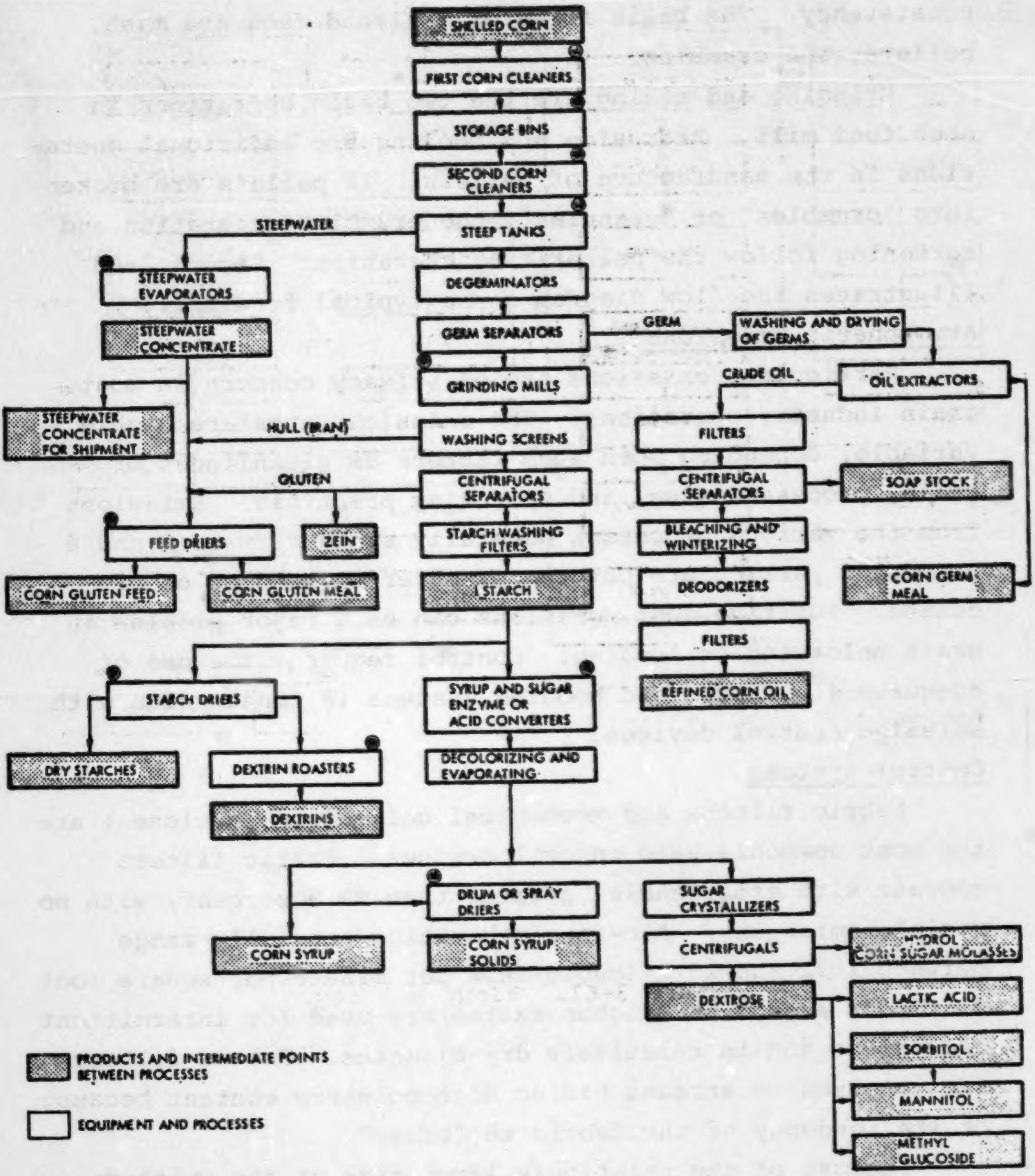

SHELLED CORN
FIRST CORN CLEANERS
STORAGE BINS
SECOND CORN CLEANERS
STEEPWATER
STEEP TANKS
STEEPWATER EVAPORATORS
DEGERMINATORS
STEEPWATER CONCENTRATE
GERM
WASHING AND DRYING OF GERMS
GERM SEPARATORS
CRUDE OIL
OIL EXTRACTORS
GRINDING MILLS
STEEPWATER CONCENTRATE FOR SHIPMENT
HULL (BRAN)
WASHING SCREENS
FILTERS
GLUTEN
CENTRIFUGAL SEPARATORS
CENTRIFUGAL SEPARATORS
SOAP STOCK
FEED DRIERS
ZEIN
STARCH WASHING FILTERS
BLEACHING AND WINTERIZING
DEODORIZERS
CORN GERM MEAL
CORN GLUTEN FEED
CORN GLUTEN MEAL
STARCH
FILTERS
STARCH DRIERS
SYRUP AND SUGAR ENZYME OR ACID CONVERTERS
REFINED CORN OIL
DRY STARCHES
DEXTRIN ROASTERS
DECOLORIZING AND EVAPORATING
DEXTRINS
DRUM OR SPRAY DRIERS
SUGAR CRYSTALLIZERS
CORN SYRUP
CORN SYRUP SOLIDS
CENTRIFUGALS
HYDROL CORN SUGAR MOLASSES
DEXTROSE
LACTIC ACID
SORBITOL
MANNITOL
METHYL GLUCOSIDE
PRODUCTS AND INTERMEDIATE POINTS BETWEEN PROCESSES
EQUIPMENT AND PROCESSES
EMISSION POINT

Figure 3-62. Wet corn milling.

consistency. The basic forms of finished feed are mash, pellets, and crumbles.

Grinding and mixing are the two basic operations in each feed mill. Extrusion and cooling are additional operations in the manufacture of pellets. If pellets are broken into "crumbles" or "granules", the crumbling operation and screening follow the pelletizing operation. Figure 3-63 illustrates the flow diagram for a typical feed mill.

Atmospheric Emissions

Particulate emissions are of primary concern in most grain industry operations. The emission rates are highly variable, depending upon such factors as cleanliness of grain, process design, and operating practices. Emissions from the various processes generally range between 2 and 8 pounds of particulate per ton of material handled or processed. Fugitive dust emissions can be a major problem in grain unloading or loading. Control requires the use of adequate enclosures and hooding systems in conjunction with emission control devices.

Control Systems

Fabric filters and mechanical collectors (cyclones) are the most commonly used control devices. Fabric filters operate with efficiencies greater than 99.9 percent, with no visible emissions. Air-to-cloth ratios generally range between 10/1 and 15/1 (cubic feet per minute per square foot of filter area); the higher ratios are used for intermittent operations and in relatively dry climates. Fabric filters are not used on streams having high moisture content because of the tendency of the fabric to "blind".

Because of the relatively large size of the emitted particulates, the collection efficiency of mechanical collectors is high. For example, cyclones on pneumatic conveying systems can operate with efficiencies above 99

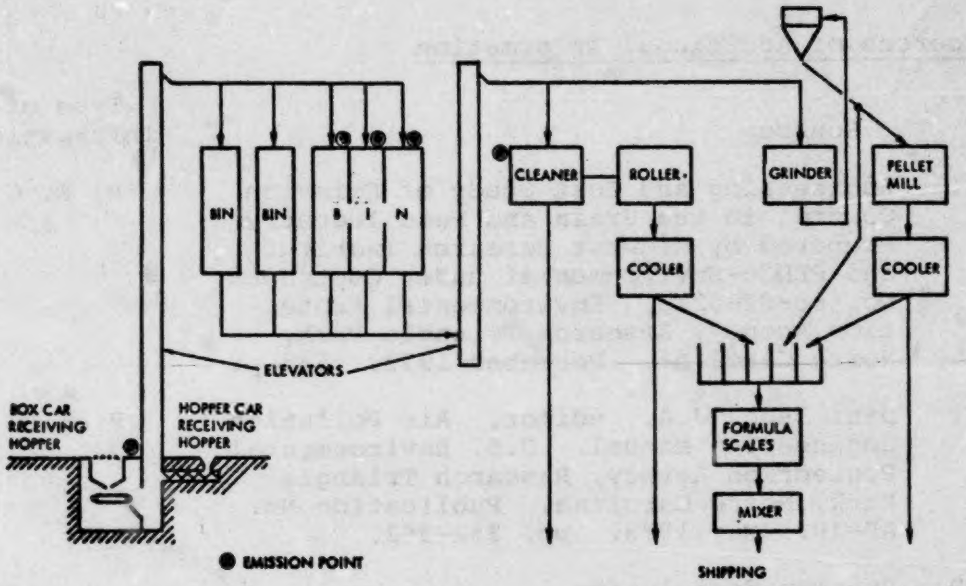

BIN
BIN
B I N
CLEANER
ROLLER
GRINDER
PELLET MILL
COOLER
COOLER
ELEVATORS
BOX CAR RECEIVING HOPPER
HOPPER CAR RECEIVING HOPPER
FORMULA SCALES
MIXER
SHIPPING
● EMISSION POINT

Figure 3-63. Feed manufacturing.

percent. At most emission sources, however, mechanical collectors allow a visible discharge even though collection efficiencies are relatively high.

Grain drying emissions and controls are discussed in Section 3.2.

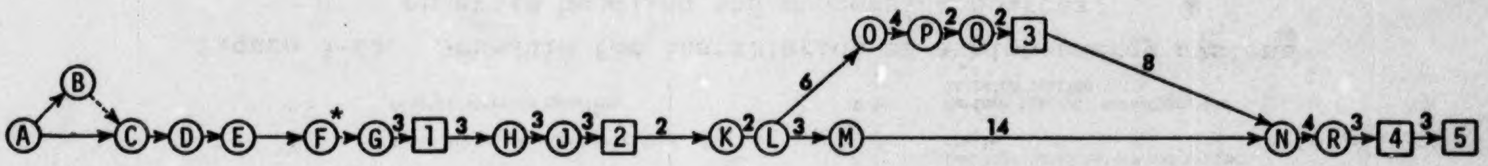
Compliance Schedules

Figures 3-64 and 3-65 illustrate expeditious schedules for installation of a baghouse and a high-energy cyclone, respectively.

Sources of Additional Information

	Source	Type of information*
1.	Engineering and Cost Study of Emission Control in the Grain and Feed Industry. Prepared by Midwest Research Institute and PEDCo-Environmental under Contract No. 68-02-0213. Environmental Protection Agency, Research Triangle Park, North Carolina. December 1973. 545 p.	P, E, C
2.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. pp. 352-362.	P, E, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

□ Milestones

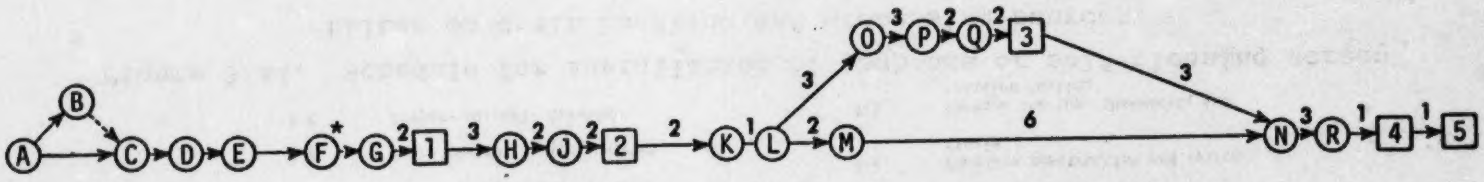
→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	45
5	Date by which final compliance is achieved.	48

Activity designation	Activity description
A-B	Conduct source tests
A-C	Perform preliminary investigation
C-D	Evaluate control alternatives
D-E	Commit funds for total program
E-F	Prepare control plan and compliance schedule for agency
F-G	Agency reviews and approves plans
G-1	Finalize plans and specifications
1-H	Procure control device bids
H-J	Evaluate control device bids
J-2	Award control device contract
2-K	Prepare assembly drawings

Activity designation	Activity description
K-L	Review and approve assembly drawings
L-M	Prepare fabrication drawings
M-N	Fabricate control device
L-O	Prepare engineering drawings
O-P	Procure construction bids
P-Q	Evaluate construction bids
Q-3	Award construction contract
3-N	Initiate on-site construction
N-R	Install control device
R-4	Complete construction and system tie-in
4-5	Perform startup, shakedown, and emission testing

Figure 3-64. Schedule for installation of baghouse or self-cleaning screen filter on grain handling and processing sources.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	9
3	Date of initiation of on-site construction or installation of emission control equipment.	22
4	Date by which on-site construction or installation of emission control equipment is completed.	29
5	Date by which final compliance is achieved.	30

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-65. Schedule for installation of a high-energy cyclone on grain handling and processing sources.

3.5.2 Grain Drying

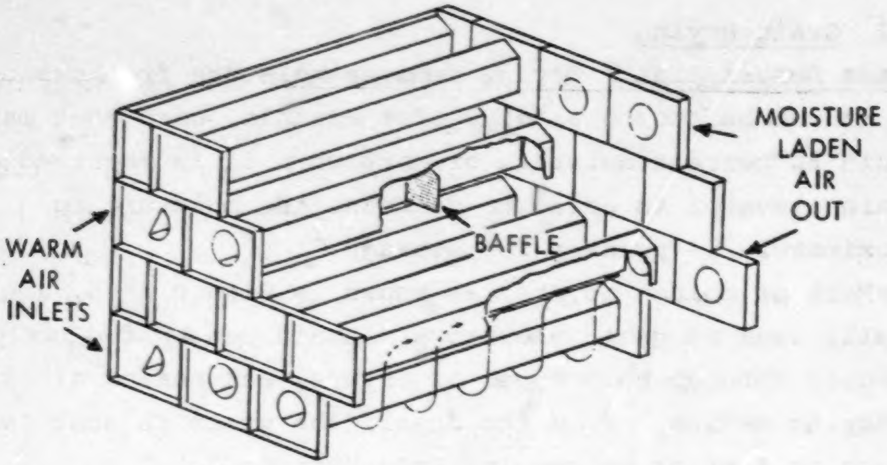
Process Description - Drying removes moisture from grain so that it can be stored safely. For example, corn that may contain 20 percent moisture or more when it is received at a grain elevator is dried to decrease the moisture to approximately 14 percent for storage.[1]

Rack or column dryers, as shown in Figure 3-66, are normally used at grain elevators. Grain can be fed continuously through both types of dryers, and heated air is the drying medium. From the dryer, the grain is sent for storage or further processing (see Section 3.5.1.).

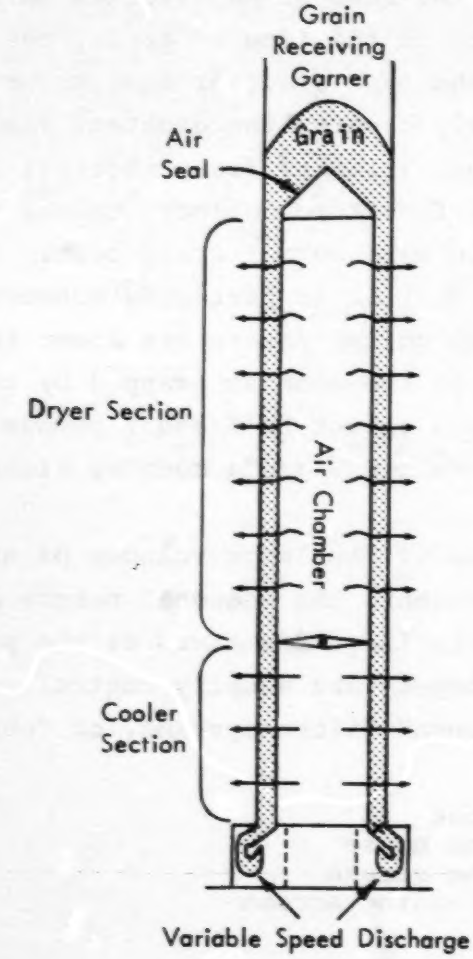
Atmospheric Emissions - The rate of particulate emissions from grain dryers depends on the type of grain, the dustiness of the grain, and the type of dryer (column or rack). Drying of soybeans usually creates the greatest visible emissions; in corn drying, a light, flaky material called "beeswings", which is difficult to collect, breaks off the corn and is emitted along with normal grain dust. Generally, 95 percent of the grain dust is in particles greater than 50 microns.[1] Emissions from column dryers are lower than from rack dryers, since some of the dust is trapped by the column of grain. Dryer emissions amount to 6 and 7 pounds per ton of grain processed at a terminal and a country elevator, respectively.[2]

Control Systems - Because of the large volumes of effluent and its high moisture content, the seasonal nature of grain drying, and the relatively large diameters of the particulate emissions, grain dryers are usually controlled with relatively low cost "screen" filter systems, of four major types:

Settling screen house
Concentrating screen house
Rotary self-cleaning screen
Sliding-bar self-cleaning screen


MOISTURE LADEN AIR OUT
BAFFLE
WARM AIR INLETS

(a) Rack Dryer


Grain Receiving Garner
Grain
Air Seal
Dryer Section
Air Chamber
Cooler Section
Variable Speed Discharge

(b) Column Dryer

Figure 3-66. Column and rack grain dryers.[1]

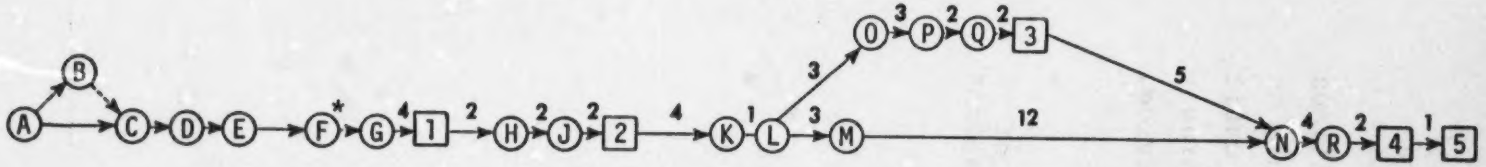
The filter material is usually 24-, 35-, or 50-mesh wire screens and occasionally 100-mesh Dacron.[1]

Compliance Schedule - Figure 3-67 illustrates an expeditious schedule for installation of a self-cleaning screen house on a grain dryer. The time interval from agency approval until full-time operation is estimated to be 37 weeks, including 12 weeks for fabrication and delivery of the control device.

Sources of Additional Information

	Source	Type of information*
1.	Engineering and Cost Study of Emission Control in the Grain and Feed Industry. Prepared by Midwest Research Institute and PEDCo-Environmental under Contract No. 68-02-0213. Environmental Protection Agency, Research Triangle Park, North Carolina, December 1973. 545 p.	P, E, C
2.	Compilation of Air Pollutant Emission Factors, 2nd edition. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. pp. 6.4-1 to 6.4-2.	E, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

□ Milestones
→ Activity and duration in weeks

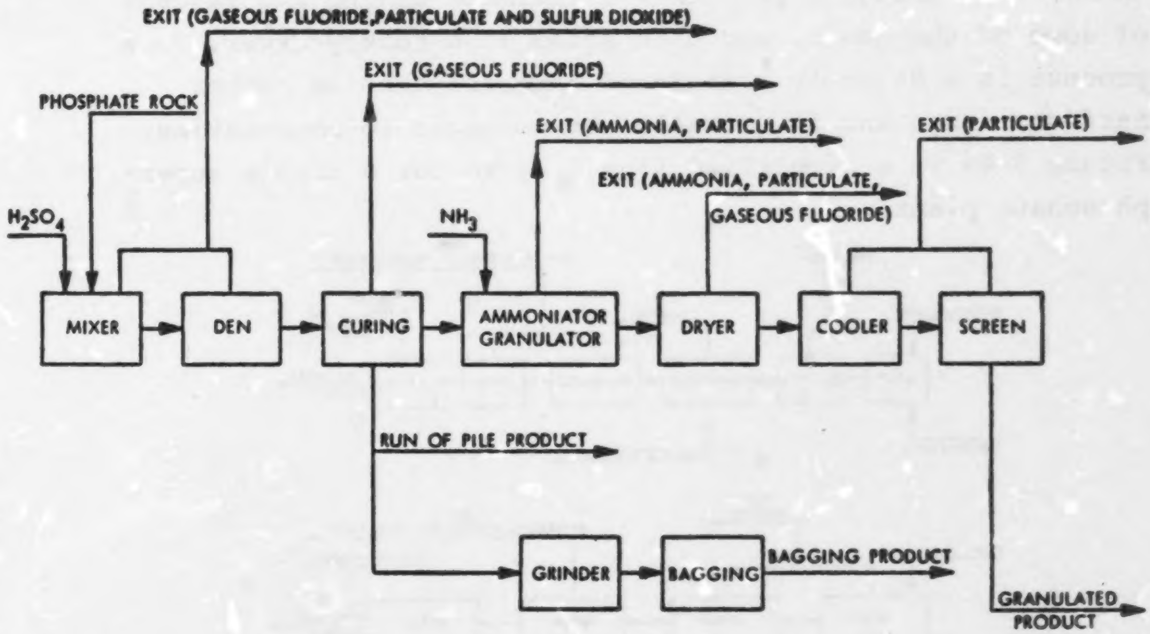
MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	25
4	Date by which on-site construction or installation of emission control equipment is completed.	36
5	Date by which final compliance is achieved.	37

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-67. Schedule for installation of self-cleaning screen on grain drying process.

3.5.3 Phosphate Fertilizer

Process Description - Among the commonly produced phosphate fertilizers are normal superphosphate, triple superphosphate, and ammonium phosphates. Normal superphosphate is produced by reacting sulfuric acid with phosphate rock. Sulfuric acid and phosphate rock are intimately mixed, dropped into a den, held for sufficient time to allow the slurry mixture to set, and then stored to permit the acidulation to go to completion. Following the curing period, the solid fertilizer is either sold as run-of-pile (ROP) product or processed further by (1) grinding and bagging or (2) granulating and reacting with ammonia to produce a granular mixed fertilizer. Figure 3-68 is a simplified flow diagram of a normal superphosphate plant.



EXIT (GASEOUS FLUORIDE, PARTICULATE AND SULFUR DIOXIDE)
EXIT (GASEOUS FLUORIDE)
PHOSPHATE ROCK
EXIT (AMMONIA, PARTICULATE)
EXIT (PARTICULATE)
EXIT (AMMONIA, PARTICULATE, GASEOUS FLUORIDE)
H_2SO_4
NH_3
MIXER
DEN
CURING
AMMONIATOR GRANULATOR
DRYER
COOLER
SCREEN
RUN OF PILE PRODUCT
GRINDER
BAGGING
BAGGING PRODUCT
GRANULATED PRODUCT

Figure 3-68. Normal superphosphate plant.

Triple superphosphate, which is also referred to as double or concentrated superphosphate, is produced through the reaction of phosphate rock and phosphoric acid. Unlike production of normal superphosphate, the production of triple superphosphate is usually a continuous operation in large plants located near phosphate rock deposits.

Production is by two major processes. The first uses a mixing cone to achieve intimate contact between the acid and rock. The resulting mix falls on a conveyor belt, which moves the material to the curing building. After curing for 30 to 60 days, the product is sold as run-of-pile or is granulated in separate equipment.

The second process produces granulated fertilizer directly. Acid and phosphate rock are placed in mixing tanks, fed through a plunger for intimate mixing and release of some of the gases, and then dried in a rotary dryer. The product is a directly granulated material that is rather hard and dense and is normally not amenable to ammoniating. Figure 3-69 is a simplified flow diagram for a triple superphosphate plant.

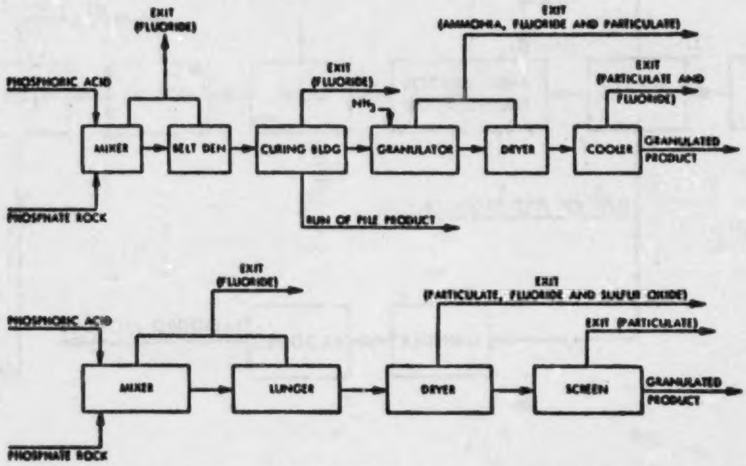

EXIT (FLUORIDE)
PHOSPHORIC ACID
MIXER
BELT DEN
PHOSPHATE ROCK
EXIT (FLUORIDE)
NH3
CURING BLDG
RUN OF PILE PRODUCT
GRANULATOR
EXIT (AMMONIA, FLUORIDE AND PARTICULATE)
DRYER
EXIT (PARTICULATE AND FLUORIDE)
COOLER
GRANULATED PRODUCT
EXIT (FLUORIDE)
PHOSPHORIC ACID
MIXER
PHOSPHATE ROCK
LUNGER
EXIT (PARTICULATE, FLUORIDE AND SULFUR OXIDE)
DRYER
EXIT (PARTICULATE)
SCREEN
GRANULATED PRODUCT

Figure 3-69. Triple superphosphate plant.

In production of diammonium phosphate, sulfuric and phosphoric acids are mixed with ammonia in a reactor and the product of the reactor is pumped as a slurry to a rotary ammoniator. Ammonia is sparged underneath the mixing bed in the ammoniator to achieve the desired ammonia level. While the equipment is rotating, agglomeration takes place and the ammoniation is completed. Diammonium phosphate granules are discharged into a rotary dryer, then conveyed through a screening station, and a rotary cooler and finally to storage. A simplified flow diagram for a diammonium phosphate plant is shown in Figure 3-70.

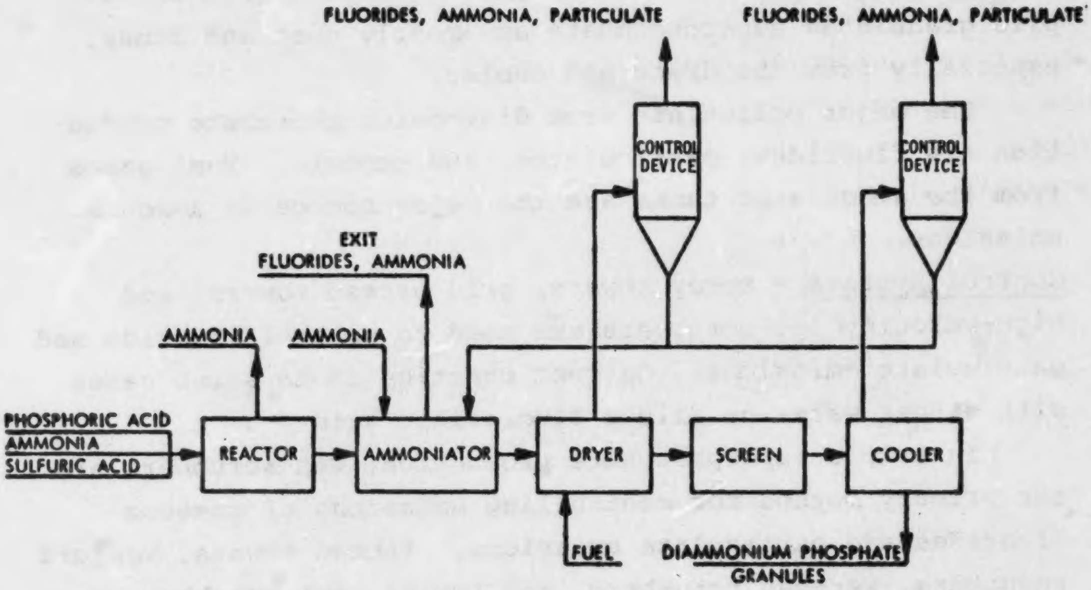

FLUORIDES, AMMONIA, PARTICULATE
FLUORIDES, AMMONIA, PARTICULATE
CONTROL DEVICE
CONTROL DEVICE
EXIT
FLUORIDES, AMMONIA
AMMONIA
AMMONIA
PHOSPHORIC ACID
AMMONIA
SULFURIC ACID
REACTOR
AMMONIATOR
DRYER
SCREEN
COOLER
FUEL
DIAMMONIUM PHOSPHATE
GRANULES

Figure 3-70. Diammonium phosphate plant.

Atmospheric Emissions - The gases released from acidulation of phosphate rock in normal superphosphate production contain silicon tetrafluoride, carbon dioxide, steam, and sulfur dioxides. From 20 to 30 percent of the fluorine in the phosphate rock is evolved during the acidulation and curing operations. Vent gases from the granulator-ammoniator may contain ammonia, silicon tetrafluoride, hydrofluoric acid, ammonium chloride, and fertilizer dust. Emissions from the final drying of granulated product include gaseous and particulate fluorides, ammonia, and fertilizer dust.

In triple superphosphate production the exit gases from plants producing nongranular products contain considerable quantities of silicon tetrafluoride, some hydrogen fluoride, and small amounts of particulates. Fluorides are also emitted from the curing buildings. Emissions from run-of-pile granulated superphosphate are mostly dust and fumes, especially from the dryer and cooler.

The major pollutants from diammonium phosphate production are fluorides, particulates, and ammonia. Vent gases from the ammoniator tanks are the major source of ammonia emissions.

Control Systems - Spray towers, grid packed towers, and high-velocity jet scrubbers are used to control fluoride and particulate emissions. Current practice is to scrub gases with either water or dilute fluorosilic acid.

In triple superphosphate production, wet scrubbers are the primary method for controlling emissions of gaseous fluorides and particulate emissions. Packed towers, venturi scrubbers, wet-pad scrubbers, and impingement scrubbers have been used.

Control of emissions from fertilizer granulation involves collection of dry dust from rotary dryers and rotary coolers, and collection of gas and dust from liquid-solid reactor units. Various high-efficiency cyclones have been used for removal of dust in exit gases, followed by wet scrubbers to further reduce the dust content and to remove the acid constituents.

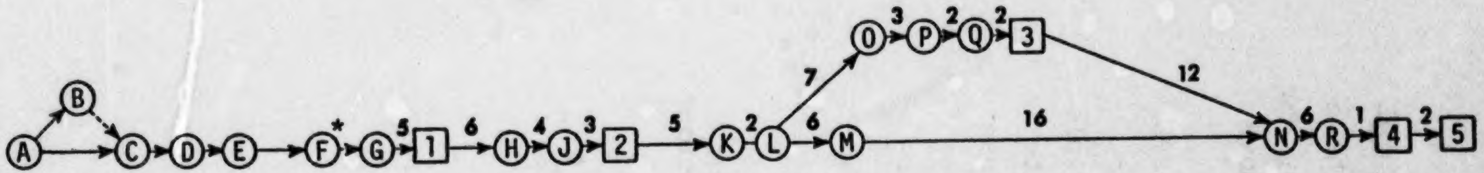
These control devices are applicable to the five NSPS categories of wet process phosphoric acid plants, superphosphoric acid plants, diammonium phosphate plants, triple superphosphate plants, and granular triple superphosphate storage facilities. (Recommended method of control is use of a spray cross-flow packed scrubber).

Compliance Schedules - Figure 3-71 illustrates an expeditious schedule for installation of a wet scrubber.

Sources of Additional Information

	Source	Type of information*
1.	Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Prepared by Midwest Research Institute for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 203 522. May 1971. pp. 313-338.	P, E, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	5
2	Date of award of control device contract.	18
3	Date of initiation of on-site construction or installation of emission control equipment.	39
4	Date by which on-site construction or installation of emission control equipment is completed.	58
5	Date by which final compliance is achieved.	60

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-71. Schedule for installation of a wet scrubber on phosphate fertilizer operation.

3.5.4 Cotton Ginning

Process Description - Cotton ginning is the mechanical separation of lint (cotton fibers) from trash (stems, leaves, unopened bolls, and dirt) and cotton seeds. The amount of trash in the seed cotton depends largely on the harvesting method. Machine-picked seed cotton contains an average of 172 pounds of trash for each 500-pound bale produced.[2] The quantity of trash per bale ranges from about 80 pounds for hand-picked cotton to almost 1200 pounds for machine scrapped cotton. Along with this trash, there is approximately 800 pounds of seeds per 500-pound bale of cotton fiber.[2] Figure 3-72 is a simplified flow diagram of a typical cotton gin plant.

The seed cotton is generally removed from trucks with a suction tube and is conveyed pneumatically throughout the ginning processes. Dryers are used to maintain moisture content of the lint within a 6.5 to 8 percent range. Each drying step is generally followed by a cleaning step to remove more trash. After the proper moisture content is reached and most of the trash has been removed, the seed cotton is fed to the gin stand. Seeds are separated from the lint cotton and stored in a seed house until they are sold to an oil mill for crushing or to a farmer for planting. The lint cotton is cleaned again to remove fly lint, fine dust, and small leaf particles and finally is condensed and pressed into low-density bales (14 pounds per cubic foot).[1]

Ginning plants generally operate 2 to 3 months per year, the schedules depending on supplies of cotton and availability of labor. Gin capacities range from less than 5 bales per hour to approximately 35 bales per hour.[2]

Atmospheric Emissions - The primary emissions from cotton gins are trash, dust, and lint. When cotton trash is

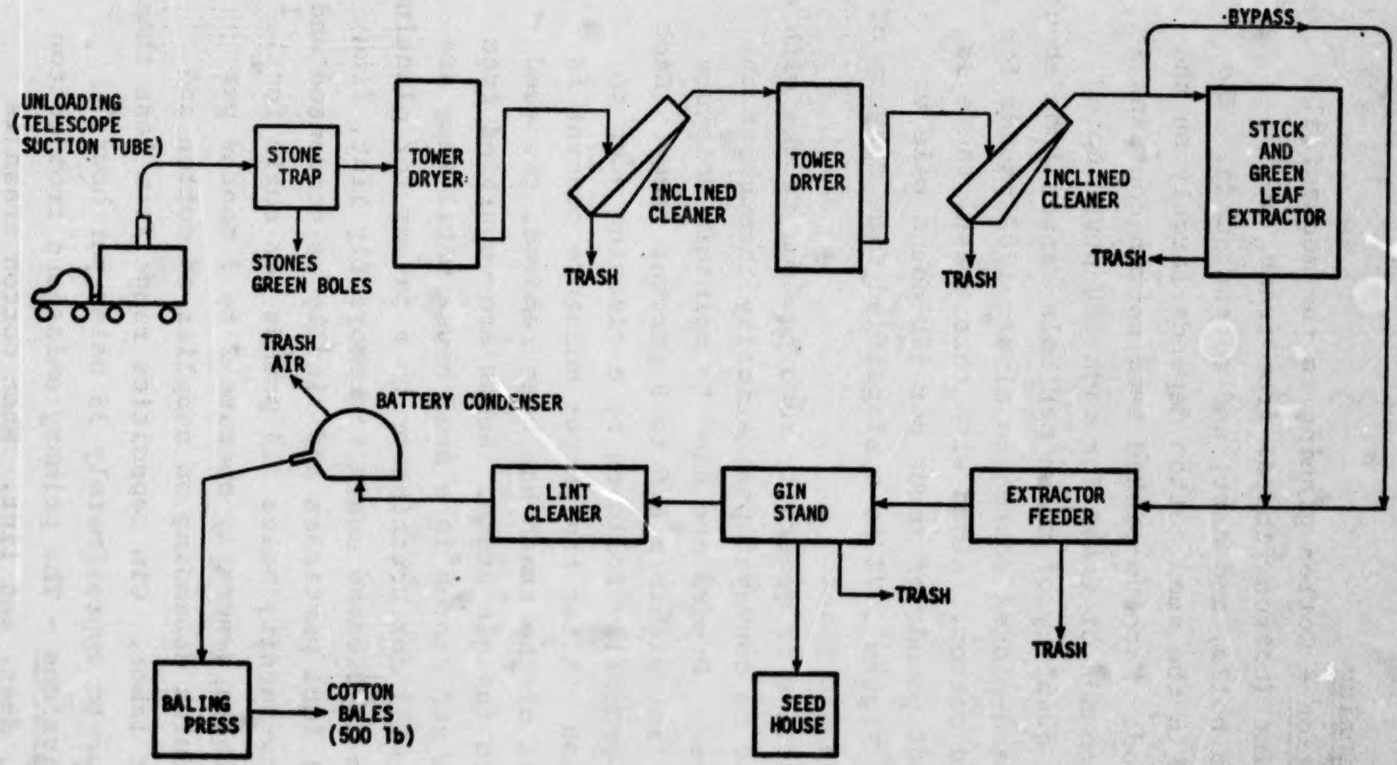

UNLOADING (TELESCOPE SUCTION TUBE)
STONE TRAP
STONES GREEN BOLES
TOWER DRYER
INCLINED CLEANER
TRASH
TOWER DRYER
INCLINED CLEANER
TRASH
BYPASS
STICK AND GREEN LEAF EXTRACTOR
TRASH
EXTRACTOR FEEDER
TRASH
GIN STAND
TRASH
SEED HOUSE
LINT CLEANER
BATTERY CONDENSER
TRASH AIR
BALING PRESS
COTTON BALES (500 lb)

Figure 3-72. Cotton ginning process.

incinerated, fly ash and smoke are emitted. Conical burners are sometimes used for incineration. The major sources of particulate from cotton gins include the unloading fan, the cleaners, and the stick and burr machine.[4] Quantity of particulate emissions varies widely with condition of the seed cotton and time and method of harvesting. A significant amount of the particulates settles out in the ginning plant. Taking this into consideration, uncontrolled emissions are approximately as follows:[4]

Process	Estimated emissions to atmosphere, lb/bale
Unloading fan	5.0
Cleaner	0.30
Stick and burn machine	0.20
Miscellaneous	1.5

The particulates may contain chemicals, fungi, bacteria, plant particles, and fly lint. The chemicals, which include pesticides and herbicides, are potentially hazardous.

Control Systems - At present, low-pressure-drop cyclones and lint filters are used at most gins. Particulate removal efficiency is approximately 90 percent for the particle size distribution found at cotton gins.[4] Filters have been added in series with cyclones to increase particulate removal efficiencies to greater than 99.9 percent. A well-designed baghouse alone can also control particulates with greater than 99.9 percent efficiency.

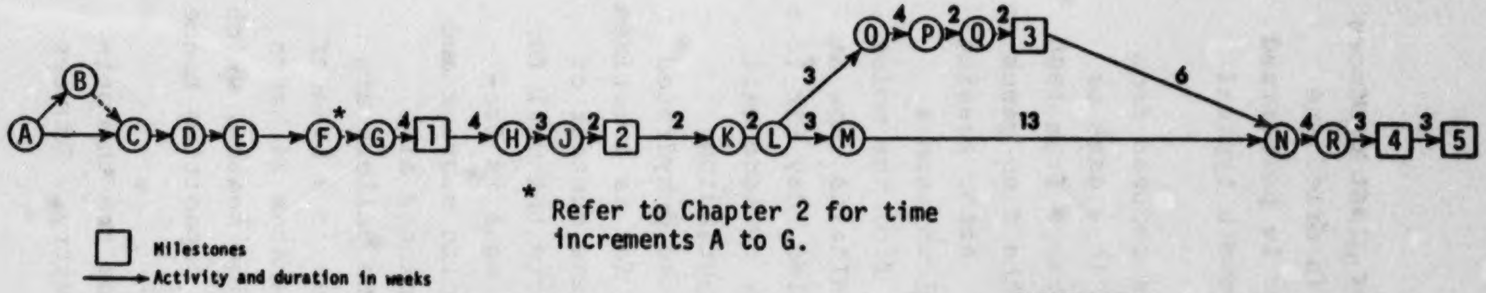
Although scrubbers can also control cotton ginning emissions effectively, they impose greater space and power requirements and also generate problems of sludge and water disposal.

Compliance Schedule - Figure 3-73 shows a reasonable schedule for installing a small packaged fabric filter. Total compliance time is estimated to be 44 weeks, including 13 weeks for control device fabrication. Installation of this device in the off season would not interrupt production.

Sources of Additional Information

	Source	Type of information*
1.	Control and Disposal of Cotton Ginning Wastes. Public Health Service, Cincinnati, Ohio. Publication No. AP-31. 1967. 104 p.	P, E, C
2.	Capital and Operating Cost Study of Model Cotton Gin Plants with Pollution Control Systems. Prepared by Research Triangle Institute and PEDCo-Environmental Specialists, Inc. for U.S. Environmental Protection Agency. Contract No. 68-02-0607. May 1974. 221 pp.	P, C
3.	Parnell, C.B., Jr. and R.V. Baker. Particulate Matter Emissions by a Cotton Gin. The Cotton Gin and Oil Mill Press. April 17, 1971. 4 p.	E
4.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. p. 6.3-1.	P, E
5.	What We Know About Air Pollution Control. The Texas Cotton Ginners Association, Dallas. March 1965. 31 p.	P, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	13
3	Date of initiation of on-site construction or installation of emission control equipment.	28
4	Date by which on-site construction or installation of emission control equipment is completed.	41
5	Date by which final compliance is achieved.	44

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-73. Schedule for installation of a small packaged fabric filter on a cotton ginning plant.

3.5.5 Alfalfa Dehydrating

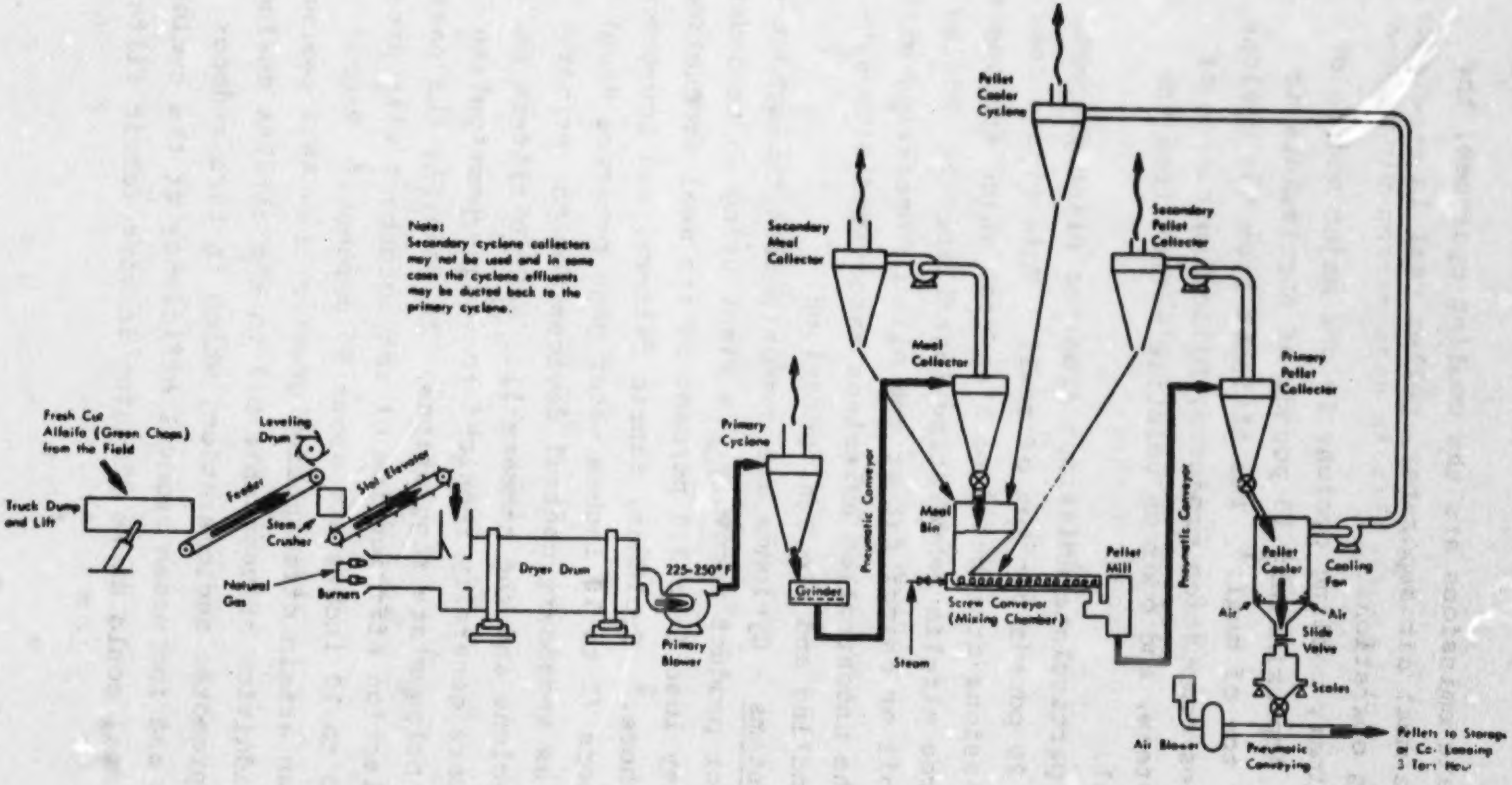
Process Description - An alfalfa dehydrating plant produces animal feed from alfalfa. Chopped alfalfa is dried and ground, then is either bagged and stored, or is pelletized or blended before shipping. Figure 3-74 shows a typical alfalfa dehydrating plant.

Moisture content of the alfalfa feed is reduced from approximately 80 percent to 8 to 10 percent in a gas- or oil-fired drum dryer. Drying temperatures range from 1800 to 2000°F where the alfalfa first contacts the flue gases to between 250 and 350°F at the dryer outlet.[1] After passing through the dryer, the alfalfa usually is blown into a primary cooling cyclone, which separates it from the moist flue gases. From the primary cyclone, the alfalfa, now at approximately 140°F, is conveyed by gas-cooled, dry air to a secondary cooling cyclone. At the secondary cyclone exit the alfalfa is at about 110°F and ready for grinding.

A hammermill is usually used to grind the dehydrated alfalfa into meal. Vegetable oil or animal fat is sometimes added during grinding to preserve the carotene content of the meal.[2] After grinding, a cyclone collects the meal for bagging, bulk storage, or pelletizing. The meal is frequently steam-extruded into pellets to minimize storage and shipping requirements. Larger dehydrating plants also produce formula feeds. For this process, the pellets are reground and the meal is mixed with additives in a blender.

A typical alfalfa dehydrating plant operates 24 hours per day, 7 days per week during the production season, which generally lasts from May to October. Plant capacities range from under 1000 to over 35,000 tons per year.[1]

Atmospheric Emissions - Particulate emissions are the primary concern of the alfalfa dehydrating industry. Sources


Fresh Cut Alfalfa (Green Chops) from the Field
Truck Dump and Lift
Feeder
Leveling Drum
Stem Crusher
Slat Elevator
Natural Gas
Burners
Dryer Drum
225-250°F
Primary Blower
Primary Cyclone
Grinder
Pneumatic Conveyor
Secondary Meal Collector
Meal Collector
Meal Bin
Steam
Screw Conveyor (Mixing Chamber)
Pellet Mill
Pellet Cooler Cyclone
Secondary Pellet Collector
Primary Pellet Collector
Pneumatic Conveyor
Pellet Cooler
Cooling Fan
Air
Air
Slide Valve
Scales
Air Blower
Pneumatic Conveying
Pellets to Storage or Car Loading 3 Tons Hour

Note: Secondary cyclone collectors may not be used and in some cases the cyclone effluents may be ducted back to the primary cyclone.

Figure 3-74. Alfalfa dehydration process.[1]

of particulate emissions are the cooling cyclones, the grinder, the meal air separator, pellet meal in separator, and blending operations.

The primary cooling cyclone is the major source of emissions. Approximately 15 pounds of particulate is emitted per ton of meal.[1] The effluent from the cyclone also includes combustion products, billowing clouds of condensed steam, and odorous volatile matter from the alfalfa meal.

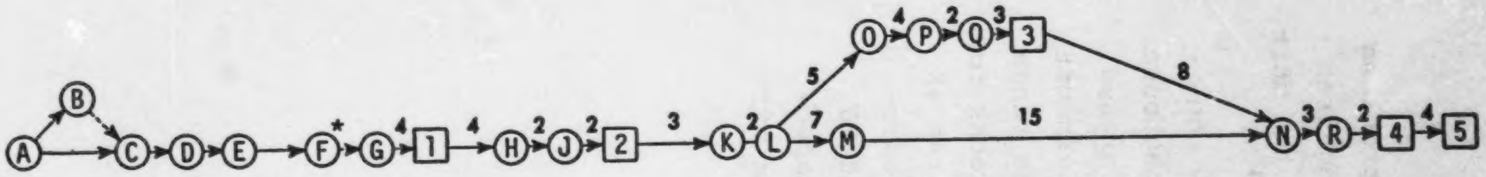
Total particulate emissions from the plant probably do not exceed 20 pounds per ton of meal.[1] This figure does not include emissions attributed to blenders, which are operated only in large alfalfa dehydrating installations. Adding vegetable oil or animal fat at the milling operation will decrease the uncontrolled emissions associated with subsequent handling and storage operations.

Control Systems - Cyclones are commonly used throughout the industry for product recovery. A plant using no secondary controls may lose 1 to 3.5 percent of its meal production to the atmosphere.[2] Cyclones, fabric filters, and low-energy wet scrubbers (2 to 10 inches water gage pressure drop) have been used as secondary control devices for the primary cooling cyclone and the hammermill. Fabric filters or wet scrubbers are generally required to reduce particulate emissions below state regulations. In general, the particulate collection efficiencies of wet scrubbers with pressure drops of 3 to 10 inches are about 60 percent.[3] Fabric filters can attain efficiencies greater than 99.5 percent.

The addition of vegetable oil to the alfalfa during grinding promotes agglomeration, which in turn reduces dustiness and increases removal efficiency of the cyclone. The oily meal could cause plugging in most fabric filters.

A high-energy air filter could be used if plugging problems occur. A pressure drop of more than 20 inches is required for maximum efficiency of a high-energy filter, and the unit operates at air-to-cloth ratios of 500/1 to 1500/1.[4]

Compliance Schedule - Figures 3-75 through 3-77 show compliance schedules for a low-energy wet scrubber, a baghouse, and a high-energy filter. Each control device is designed to control a primary cooling cyclone with a typical exhaust rate of 30,000 acfm at 225°F. Installation schedules range from 41 weeks for the high-energy air filter to 53 weeks for the small baghouse. A low-energy wet scrubber requires 48 weeks for installation. In all cases, fabrication represents the major time increment, totalling 14, 16, and 20 weeks for the air filter, baghouse, and scrubber, respectively. Any control device could be installed in the off season and would not interrupt production.



* Refer to Chapter 2 for time increments A to G.

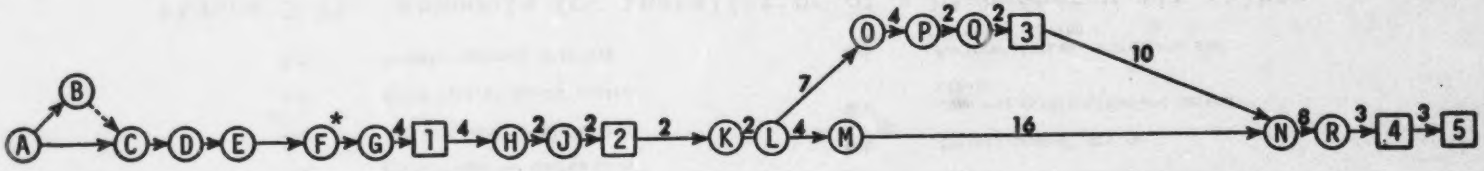
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	31
4	Date by which on-site construction or installation of emission control equipment is completed.	44
5	Date by which final compliance is achieved.	48

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-75. Schedule for installation of a low-energy wet scrubber on an alfalfa dehydration process.



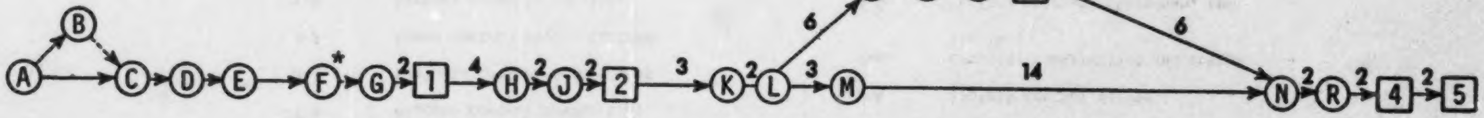
* Refer to Chapter 2 for time increments A to G.

☐ Milestones
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	31
4	Date by which on-site construction or installation of emission control equipment is completed.	52
5	Date by which final compliance is achieved.	55

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-76. Schedule for installation of small fabric filter on an alfalfa dehydration process.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	29
4	Date by which on-site construction or installation of emission control equipment is completed.	39
5	Date by which final compliance is achieved.	41

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-77. Schedule for installation of a high-energy air filter on an alfalfa dehydration process.

Sources of Additional Information

	Source	Type of information*
1.	Engineering and Cost Study of Emission Control in the Grain and Feed Industry. Prepared by Midwest Research Institute and PEDCo-Environmental under Contract No. 68-02-0213. Environmental Protection Agency, Research Triangle Park, North Carolina. December 1973. 545 p.	P, E, C
2.	Alfalfa Dehydrating Engineering Guide For Processing OEPA Air Pollution Permits. Industrial Pollution Section, OEPA, Columbus, Ohio. July 1973. p. 6-1-1 to 6-1-9.	P, E, C
3.	Particulate Emissions from Alfalfa Dehydrating Plants - Control Costs and Effectiveness. Prepared by American Dehydrators Association under Grant No. R801446. Environmental Protection Agency, Washington, D.C. January 1974. 122 p.	
4.	HEAF. Manufactures Bulletin 113 5/75. Anderson 2000, College Park, Georgia. May 1975. 4 p.	

*P = Process description
E = Emission rates
C = Control devices

3.6 PRIMARY METALLURGICAL PROCESSES

3.6.1 Metallurgical Coke

Process Description - Coke, an essential component in the manufacture of iron and steel, is the residue from the destructive distillation of coal. By-product coking, which is by far the most common process in the United States, is a batch process generally involving batteries of 50 ovens or more. These slot coke ovens, in which coal is heated in the absence of air, are narrow refractory channels. Gas-fired flues between adjoining ovens keep the ovens at coking temperature.

Initially, coal is blended to give uniform coking characteristics, then pulverized in hammermills and transferred to a storage silo above the battery of ovens. A weighed portion of coal is then discharged into a larry car, which is a wide-gauge vehicle fitted with coal hoppers. The coal is transferred from the hoppers into three to six opened coal-charging ports above an empty oven. The oven-charging ports are then closed for the duration of the coking cycle.

As the charged coal is heated, a wide range of organic compounds are emitted, and collected in standpipes or exhaust flues. These gases are sent to a by-product recovery section for separation and recovery of such by-products as tar, light aromatic compounds, and ammonia liquor. The remaining coke oven gas containing methane, hydrogen, and carbon monoxide is used as fuel in the plant or flared.

Upon completion of the coking cycle, both oven end doors are opened and the incandescent coke is forced into a hot-coke car at one end of the oven by a large pusher ram at the opposite end. The hot-coke car, or quenching car, moves the coke to a quenching tower, a chimney-like structure in which the coke is deluged with water. The damp, quenched coke is then deposited in a sloping wharf, in which it drains and cools to uniform moisture content and temperature. Figure 3-78 illustrates the overall coking process.

Atmospheric Emissions - The primary pollutants from coke manufacture are coal and coke dust, sulfur compounds, light hydrocarbons and aromatics, carbon monoxide, nitrogen oxides, and reduced sulfur compounds. Emissions can occur during coal handling, charging, coking, pushing, and quenching. The emission sources of primary concern are charging pots, oven doors and take-offs, pushing and quenching operations, and coke-oven gas combustion stacks.

Major emissions occur at the point of charging the coal to the hot oven, since the rapid heating of the coal causes volatilization of gases from the coal mass. These gases escape to the atmosphere through the charging ports, larry car hoppers, and drop sleeves unless controlled. Emissions also occur in the early stages of coking because of leaks at the charging ports, off-takes, and around the sealed end doors.

Coke-oven gas recovered in the by-product recovery system typically contains 3.5 to 4.5 grains per standard cubic foot of hydrogen sulfide. Use of the coke-oven gas for fuel in heating or underfiring the coke ovens and for other combustion operations causes sulfur oxide emissions unless the hydrogen sulfide has been removed.

Emissions resulting from discharge of the coke from the ovens consist of smoke from any incompletely coked coal and dust released as the coke is pushed into the hot-coke car.

Quenching of the hot coke results in a fine coke breeze formed during the pushing of the hot-coke car and as water

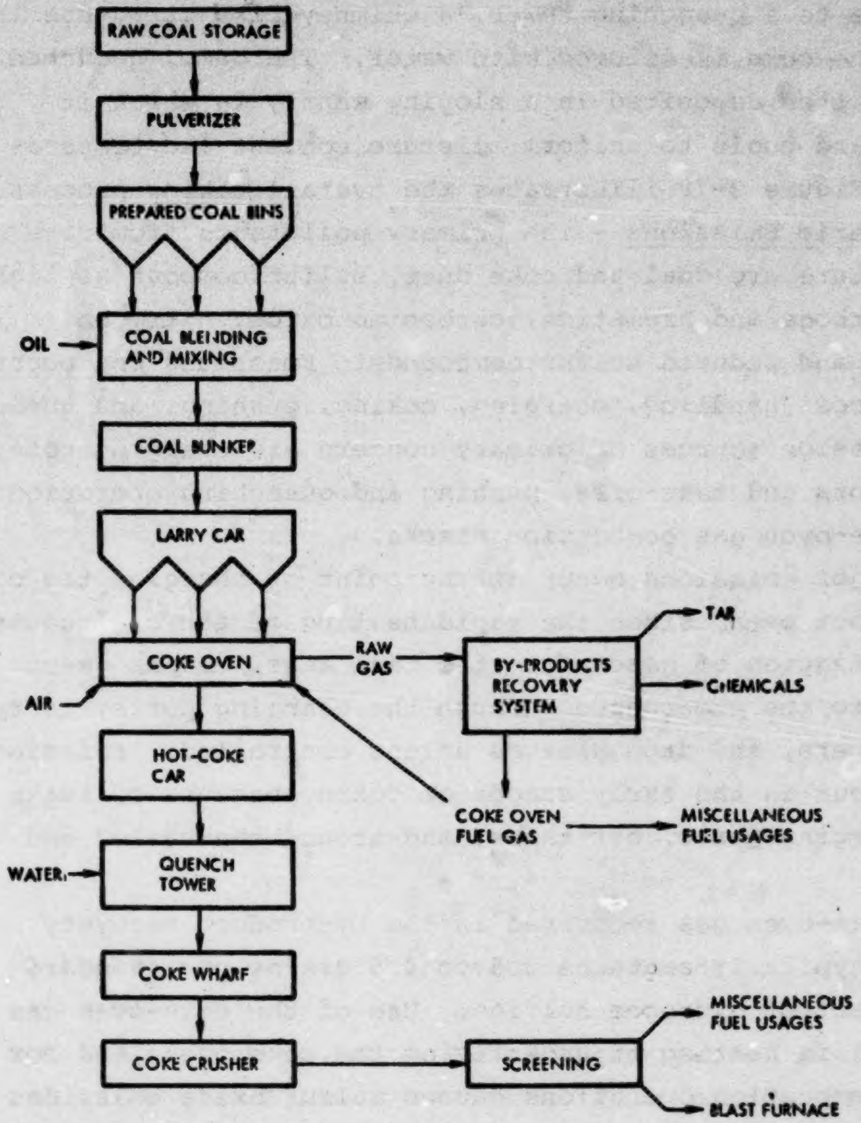

RAW COAL STORAGE
PULVERIZER
PREPARED COAL BINS
OIL
COAL BLENDING AND MIXING
COAL BUNKER
LARRY CAR
COKE OVEN
AIR
RAW GAS
BY-PRODUCTS RECOVERY SYSTEM
TAR
CHEMICALS
HOT-COKE CAR
COKE OVEN FUEL GAS
MISCELLANEOUS FUEL USAGES
WATER
QUENCH TOWER
COKE WHARF
COKE CRUSHER
SCREENING
MISCELLANEOUS FUEL USAGES
BLAST FURNACE

Figure 3-78. Metallurgical coke manufacturing.

is flash-evaporated within the coke itself. In addition, use of contaminated water for quenching can cause emissions of ammonia and phenol vapors.

Control Systems - A procedure commonly used to reduce emissions during coal charging is termed "charging on the main." A steam ejector in the ascension pipe produces a vacuum in the oven during the charging period and the gases are pulled into the gas collector main. Although it has undergone some improvements, this technique alone is generally considered to be ineffective. Two improvements are charging on the main with staged or sequential charging and pipeline charging. Charging on the main with staged charging can be readily incorporated into an existing plant. Features of this system include sequencing of larry car coal charging to prevent a surge of pollutant-laden gases, maintaining some portion of charge in the hopper car to prevent the escape of gases at the port, and maintaining a steady negative pressure in the oven to continually draw off the evolved gases. Removal of gases from both ends of the oven should be practiced because of the possibility of blockage of the free space. Dual collecting mains or jumper pipes can be used for this purpose.

Pipeline charging involves preheating coal to drive off moisture and transporting it by pipeline. Although a 40 to 50 percent increase in oven productivity can be realized with this method, it is considerably more expensive, requiring far more extensive equipment changes than staged charging. Due to these changes, pipeline charging systems cannot be readily retrofitted. Furthermore, the capacity of the by-product recovery system must be increased to accommodate the increase in oven capacity.

Several systems have been considered for control of pushing emissions. One operating system consists of an enclosed quench car, which is attached to a second car that carries a wet scrubber unit. During the pushing operation, emissions are collected in the enclosed car and withdrawn through ductwork between the cars to the wet scrubber unit. A traveling hood system has also been used for emission control. A hood is installed on a track so that it can be moved to cover the oven in the battery being pushed. The hoods are normally ducted to a stationary scrubber. Another control technique is to install a shed enclosing the entire coke side of the battery. The dust and smoke collected in the shed are then exhausted through a particulate control device such as a scrubber or a wet ESP.

During coking, the generated gases and particulate are collected from the oven by an off-take system which maintains a slightly positive pressure in the oven. This positive oven pressure provides an oxygen deficient atmosphere for coking, but leads to door and top-side leaks. Good practices for maintenance and replacement of doors can minimize such emissions. New designs such as vented flue doors can be utilized to reduce coking door emissions. Vented flue doors provide a passage for gases that are generated at the bottom of the oven during the beginning of the coking cycle to the free space in the top of the oven. High pressures at the base of the oven are caused by the lack of gas passages through the coal mass early in the cycle. As coking proceeds, fissures form in the mass and reduce the pressure in the bottom of the oven.

Particulate emissions from the coke battery stack can be controlled by wet and dry ESP's. Charged-droplet scrubbers are also being considered for particulate control.

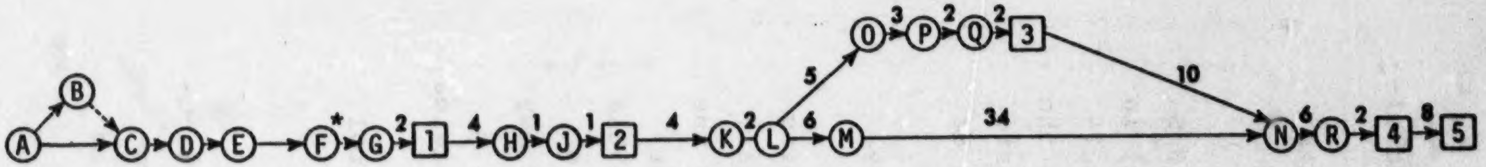
Coke oven gas, after by-product recovery, may require desulfurization before it is used as fuel. For removal of hydrogen sulfide from coke oven gas, the vacuum carbonate process is the most widely accepted method applied on a large scale. Hydrogen sulfide is absorbed by a sodium carbonate solution and then released in a concentrated H_2S stream by steam stripping. By this method the H_2S level in the gas stream can be reduced by about 93 percent. A sulfur-recovery plant is normally used in conjunction with the vacuum carbonate process to convert the recovered H_2S into elemental sulfur. Other desulfurization processes such as the Stretford process may also be used.

Generally, quenching emissions can be controlled by installation of baffles, with or without water sprays, in existing quench towers. Other techniques are quenching coke by spraying it on a controlled moving grate or rotary table, which is ducted to a wet scrubber, and quenching the coke with an inert gas such as nitrogen instead of water.

Compliance Schedules - Figure 3-79 illustrates a reasonable schedule for installation of staged charging at existing coke oven batteries. Differences in existing equipment may alter certain parts of the schedule.

Figures 3-80 through 3-82 represent estimated schedules for installation of a closed car system, a shed, and a traveling hood system, respectively, for emissions control during pushing.

Figure 3-83 illustrates a reasonable schedule for installation of a coke oven gas desulfurization system. When desulfurization is not used at a coke battery, particulate emissions can be controlled by a wet or dry electrostatic precipitator. A complete door modification may be necessary to minimize leakage from the coke oven doors.



* Refer to Chapter 2 for time increments A to G.

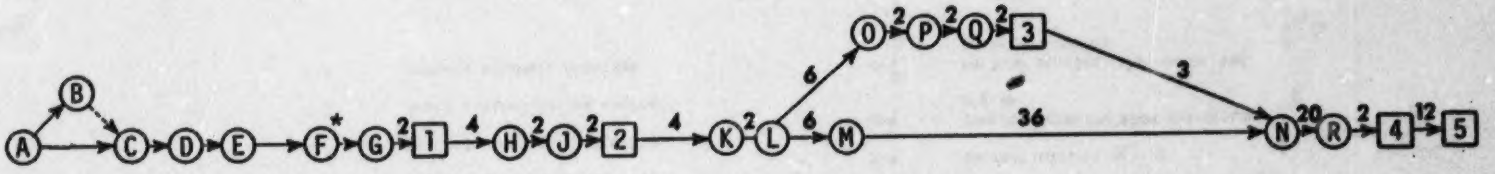
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	8
3	Date of initiation of on-site construction or installation of emission control equipment.	26
4	Date by which on-site construction or installation of emission control equipment is completed.	62
5	Date by which final compliance is achieved.	70

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-79. Schedule for larry car modifications required for staged charging on a coke oven battery.



* Refer to Chapter 2 for time increments A to G.

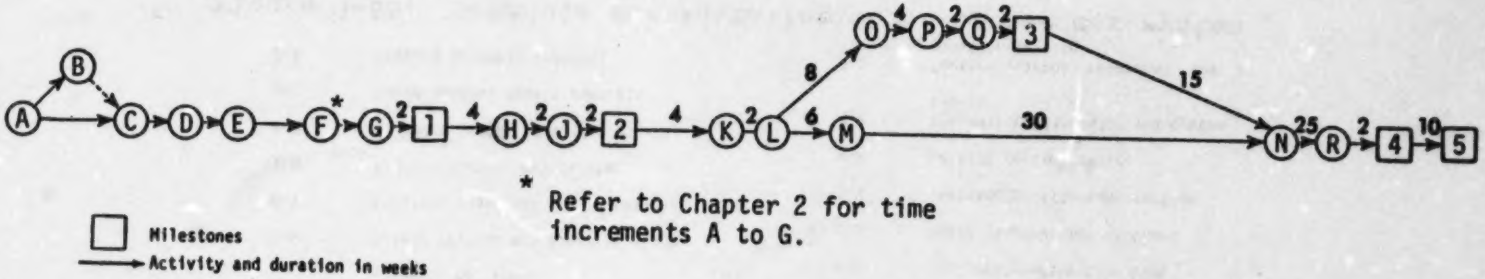
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	28
4	Date by which on-site construction or installation of emission control equipment is completed.	80
5	Date by which final compliance is achieved.	92

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-80. Schedule for installation of closed car system for controlling coke-pushing emissions.

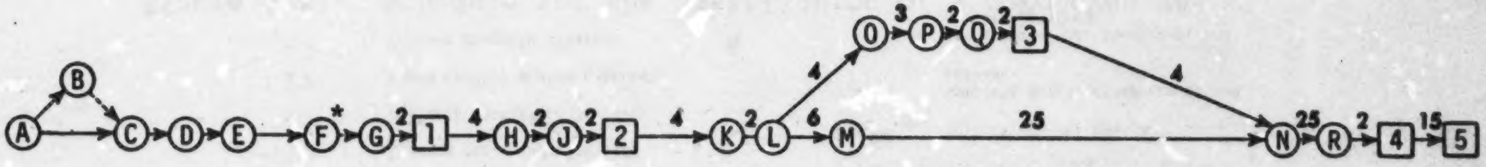


* Refer to Chapter 2 for time increments A to G.

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	32
4	Date by which on-site construction or installation of emission control equipment is completed.	79
5	Date by which final compliance is achieved.	89

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-81. Schedule for installation of a shed for controlling coke-pushing emissions.



* Refer to Chapter 2 for time increments A to G.

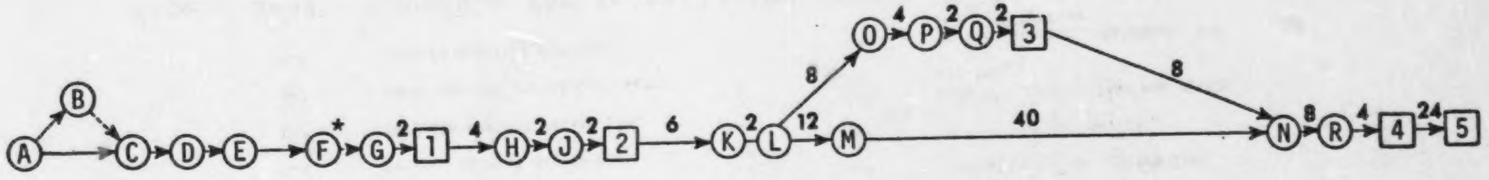
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	27
4	Date by which on-site construction or installation of emission control equipment is completed.	74
5	Date by which final compliance is achieved.	89

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-82. Schedule for installation of a traveling hood to control coke-pushing emissions.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	34
4	Date by which on-site construction or installation of emission control equipment is completed.	82
5	Date by which final compliance is achieved.	106

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

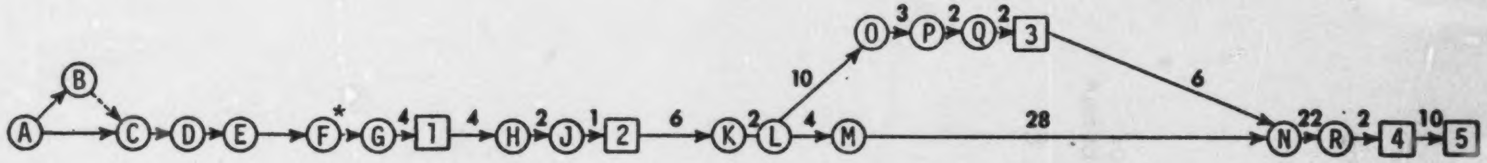
Figure 3-83. Schedule for the installation of a coke oven gas desulfurization system.

Figures 3-84 and 3-85 show expeditious schedules for door modification and for installation of a wet or dry ESP, respectively.

Sources of Additional Information

	Source	Type of information*
1.	Barnes, T.M., et al. Evaluation of Process Alternatives to Improve Control of Air Pollution from Production of Coke. Prepared by Battelle Memorial Institute for the U.S. Public Health Service, Cincinnati, Ohio. NTIS No. PB-189-266. January 1970. 178 p.	P, E, C
2.	Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition. Volume 19. Interscience Publishers, New York, 1969. p. 383	C
3.	Control Techniques for Sulfur Oxide Air Pollutants, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. November 1972.	E, C
4.	Coke Ovens - Particulate Emission Control Analysis, Empire-Detroit Steel, Portsmouth Works. Prepared by PEDCo-Environmental Specialists, Inc. for Ohio Environmental Protection Agency, Columbus, Ohio. May 1975. 53 p.	P, E, C
5.	Kulujian, N.J. By-Product Coke Battery Compliance Evaluation. Prepared by PEDCo-Environmental Specialists, Inc. for U.S. Environmental Protection Agency under Contract No. 68-02-1321, Task No. 13. June 1975.	P, E

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

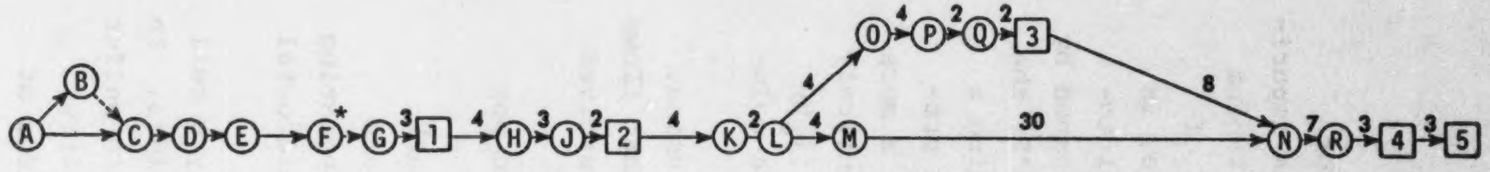
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	11
3	Date of initiation of on-site construction or installation of emission control equipment.	36
4	Date by which on-site construction or installation of emission control equipment is completed.	75
5	Date by which final compliance is achieved.	85

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-84. Schedule for converting to vented doors to control coke oven emissions.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	62
5	Date by which final compliance is achieved.	65

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
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G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-85. Schedule for installation of a wet or dry ESP to control particulate emissions from coke oven battery stacks.

3.6.2 Primary Aluminum

Process Description - Bauxite is the principal ore of aluminum. It consists of aluminum oxide and various impurities, such as iron oxide, aluminum silicate, and titanium dioxide. The production of alumina, which consists of separating it from the impurities in the bauxite ore, is accomplished entirely by chemical means. In the Sainto-Claire Deville process, the sodium aluminate is prepared by calcining the bauxite with sodium carbonate at 2000°F; the calcined material is then washed with alkali, yielding a sodium aluminate solution from which the alumina is precipitated by carbon dioxide. In the Bayer process, a more recent development, the separation is carried out entirely in the aqueous phase, taking advantage of the solubility equilibria of the alumina hydrates in a caustic soda solution.

Aluminium is produced electrolytically from alumina. The alumina is decomposed by a continuous current that flows through the electrolytic cell containing alumina dissolved in molten cryolite.

The electrolyte cell consists of a carbon-lined box containing a pad of molten aluminium that serves as a cathode, a carbon anode, and the alumina-cryolite bath. Usually 100 cells, commonly called reduction pots, are connected in series to form a potline, each plant operating three to ten potlines. Figure 3-86 illustrates a pictorial flow chart of primary aluminum production.

Atmospheric Emissions - Emissions from the electrolyte cell consists primarily of particulates containing fluorides. In addition to fluorine, exhausts from the cells contain sulfur dioxide from the sulfur impurities in the anodes, tarry hydrocarbons, alumina and carbon particles, and oxides of carbon.

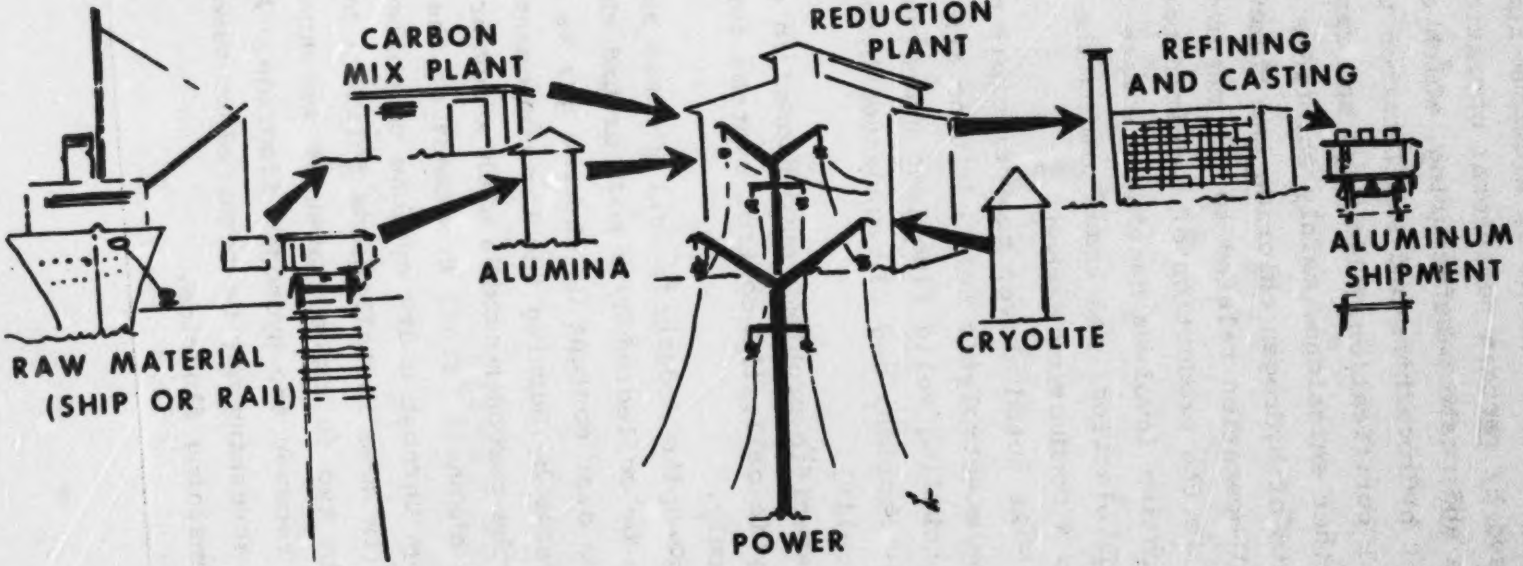

CARBON MIX PLANT
REDUCTION PLANT
REFINING AND CASTING
ALUMINA
ALUMINUM SHIPMENT
CRYOLITE
RAW MATERIAL (SHIP OR RAIL)
POWER

Figure 3-86. Aluminum reduction process.

Other atmospheric emissions in aluminum reduction plants are caused by certain peripheral operations. Among these are anode and paste manufacturing, which emits high-molecular-weight hydrocarbons and small carbon particles. The molten metal purification, alloying, and casting operations cause further emissions, mainly chlorides of aluminum and small amounts of hydrogen chloride and chlorine. A third peripheral operation related to the manufacture of anode and paste is the production of calcined petroleum coke. This operation involves heating the material to drive off moisture and volatiles, and transforming the carbon from an insulating to a conducting carbon.

Control Systems - As noted above, the principal potential pollutants in the electrolytic cell effluent are (1) particulate solids, including solid fluorides and alumina, (2) gaseous hydrogen fluoride, and (3) condensed hydrocarbons (from Soderberg cells).

Because of specific problems encountered in use of each type of electrolytic cell, the control systems for each are discussed separately.

1) Vertical-Spike Soderberg Cell - Gases and dust from the bath can be collected by a hood around the bottom of the anode. The dust content of the raw gas is reduced in the collection system by burning the tar components in combination with the carbon monoxide with a burner located in the collection channel. Final treatment of the gas consists of passage through a dry cyclone to collect the coarse particles (in some installations followed by a filter) followed by two to three stages of wet scrubbers that use water to recover the hydrogen fluoride. A final stage of alkaline scrubbing may be required to remove sulfur dioxide and the remaining fluoride.

2) Horizontal-Spike Soderberg Cells - The arrangement of the spikes in horizontal-spike soderberg cells makes it difficult to effect a good seal around the anode, and therefore large quantities of diluting air enter the gas cleaning system. The dilution is so great that combustion to destroy the tars is neither economical nor feasible.

One installation in Canada reportedly has overcome the problem of tar interference in the wet scrubber operation by using a turbulent-bed scrubber. The combined action of an upward flow of gas and the downward flow of the scrubbing liquid maintains the spheres in a loose assembly and promotes intimate mixing. Turbulence around the loose spheres keeps them free of tars and dirt. Field tests have shown that this type of scrubber can remove 90 percent or more of hydrogen fluoride.

3) Prebaked Cells - When cells with prebaked anodes are used, it is difficult to draw off furnace gases in concentrated form directly from the cells because of the large number of anodes. On these pots, an exhaust hood usually encloses the active area and maintains it at a slightly negative pressure.

Pollution control with the prebaked cell consists of a dry cyclone or electrostatic precipitator for removal of particulates, followed by a wet scrubber to absorb the highly soluble hydrogen fluoride and the remaining traces of fluoride particulates.

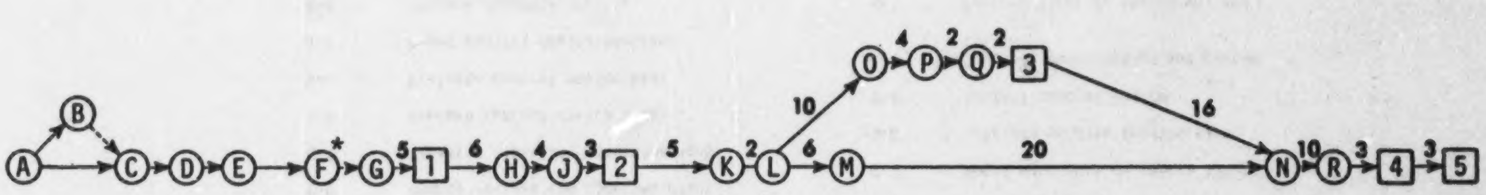
A more recent method for recovering gaseous fluorides from prebaked potlines entails the use of a heavy bed of alumina, which is continually added on the upper crust of the cell. Contaminants are removed by filtering the gases through the bed of alumina; stray particulates are captured by a baghouse further downstream.

Compliance Schedules - Figures 3-87, 3-88, and 3-89, illustrate expeditious schedules for installation of a wet scrubber system, a fabric filter, and an electrostatic precipitator on a primary aluminum reduction operation. The complexity of the ductwork and hooding systems required for effective control was considered in developing the schedules. Additional time was included to reflect the extra work required for design, fabrication, and installation. No compliance schedule is shown for installation of dry cyclones or afterburners, since these devices can be installed relatively quickly and construction can be accomplished within the elapsed time shown for any of the other control devices mentioned.

Sources of Additional Information

	Source	Type of information*
1.	Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition. Volume 1. Interscience Publishers, New York. 1967.	P
2.	Air Pollution Control Field Operations Manual, Revised Edition. Volume III. Prepared by System Development Corp. for the U.S. Environmental Protection Agency, Raleigh, North Carolina under Contract No. CPA 70-122. February 1972.	P
3.	Rush, D. et al. Air Pollution Abatement on Primary Aluminum Potlines. Journal of the Air Pollution Control Association, 23(2):98-104, 1973.	P, E, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

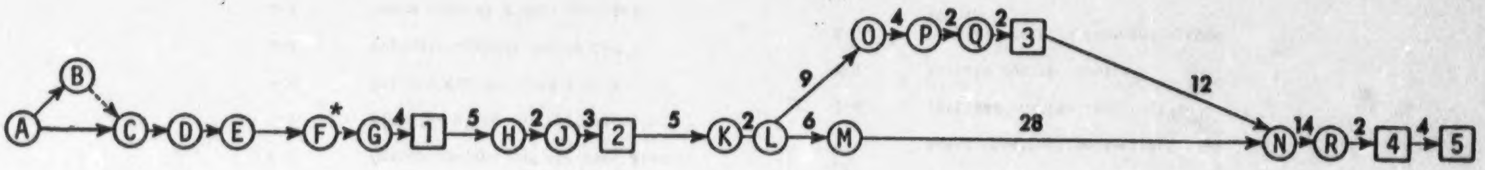
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	5
2	Date of award of control device contract.	18
3	Date of initiation of on-site construction or installation of emission control equipment.	43
4	Date by which on-site construction or installation of emission control equipment is completed.	72
5	Date by which final compliance is achieved.	75

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-87. Schedule for installation of a wet scrubber on a primary aluminum reduction operation.



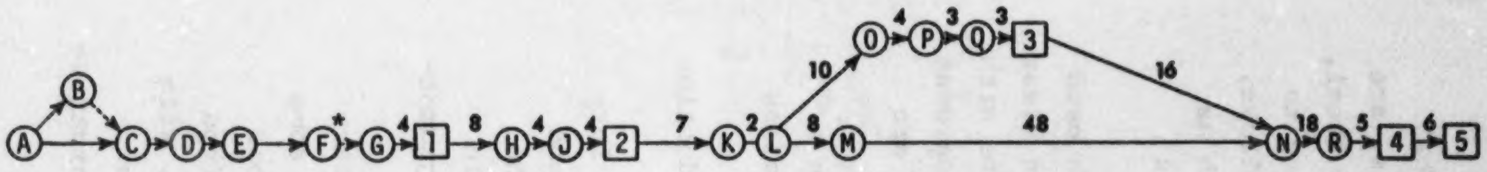
* Refer to Chapter 2 for time increments A to G.

☐ Milestones
→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	71
5	Date by which final compliance is achieved.	75

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-88. Schedule for installation of fabric filter on a primary aluminum reduction operation.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	20
3	Date of initiation of on-site construction or installation of emission control equipment.	49
4	Date by which on-site construction or installation of emission control equipment is completed.	108
5	Date by which final compliance is achieved.	114

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-89. Schedule for installation of an electrostatic precipitator on a primary aluminum operation.

3.6.3 Ferroalloys

Process Description - Ferroalloys, the generic term for alloys consisting of iron and one or more other metals, are used for deoxidation, alloying, and graphitization of steel. They can be classified into three basic types according to the major nonferrous constituent: (1) silicon-based alloys, such as ferrosilicon; (2) manganese-based alloys, such as ferromanganese; and (3) chromium-based alloys, such as ferrochromium.

Blast furnaces and electric arc furnaces are both used to produce ferroalloys. Ferromanganese is produced in blast furnaces by the reduction of iron ore and manganese ore with coke in the presence of limestone. Approximately 75 percent of the ferroalloys, however, are produced in electric arc furnaces.

Other ferroalloy manufacturing processes, used to a much lesser extent, are the alumino silico-thermic process and the electrolytic deposition process. Figure 3-90 presents a detailed flow diagram for a ferroalloy production process.

Atmospheric Emissions - Particulates emitted from the furnace are the primary emission problem. The chemical and physical properties of the particulates depend upon the alloy being produced and the type of furnace. Particle sizes generally range from 0.1 to 1.0 micron, with a geometric mean of approximately 0.3 micron.

Particulate emissions from silicon alloy manufacture contain a high percentage of SiO_2. They also contain some tars and carbon caused by the use of coal, coke, or wood chips in the charge. Chromium furnaces produce SiO_2 fume similar to that generated in a ferrosilicon operation, with some additional chromium oxides. Manganese operations produce a brown fume, largely a mixture of SiO_2 and manganese oxides.

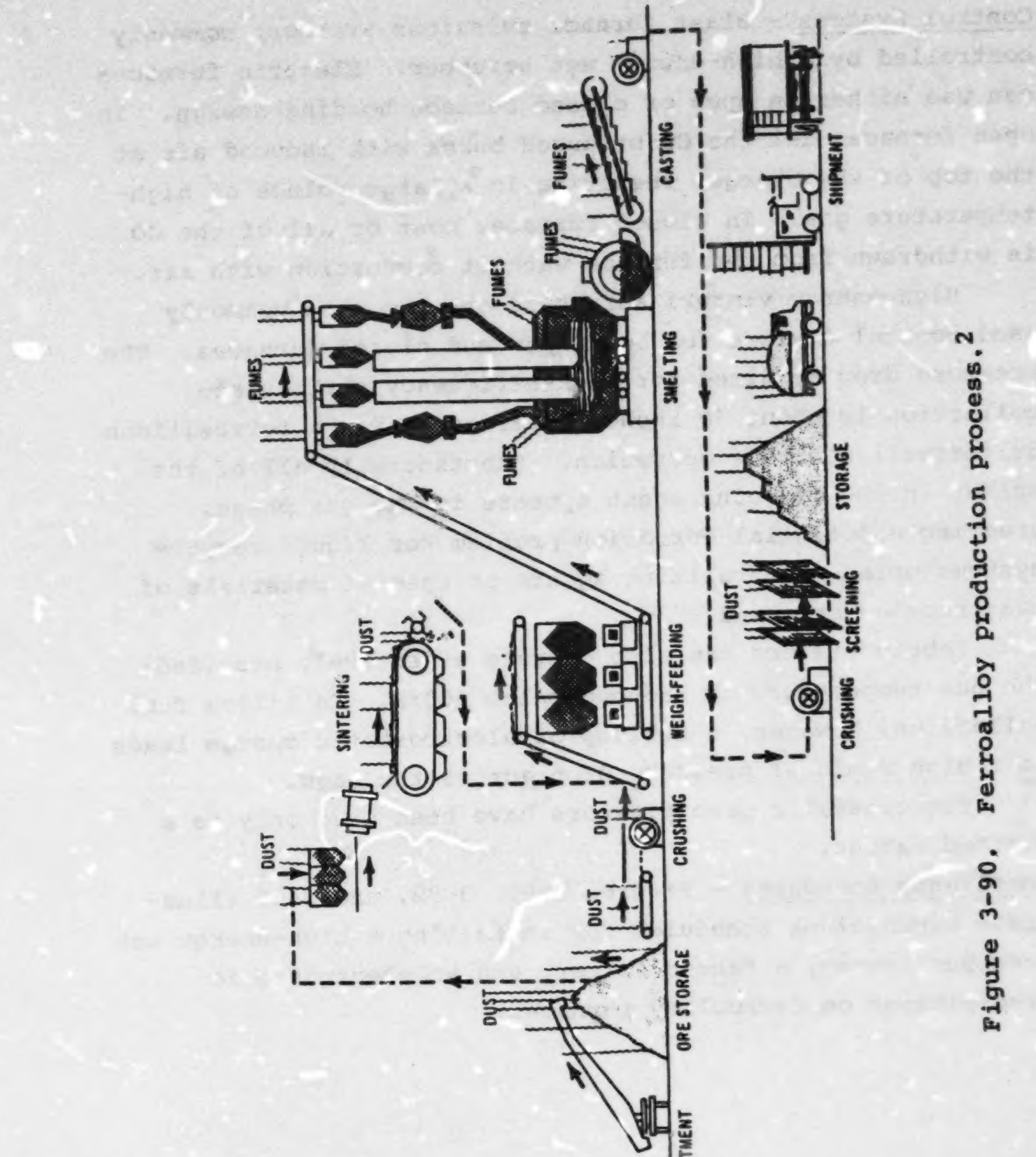

UNLOADING ASSORTMENT
DUST
ORE STORAGE
DUST
DUST
CRUSHING
DUST
SINTERING
DUST
WEIGH-FEEDING
FUMES
FUMES
FUMES
SMELTING
FUMES
FUMES
CASTING
CRUSHING
DUST
SCREENING
STORAGE
SHIPMENT

Figure 3-90. Ferroalloy production process.2

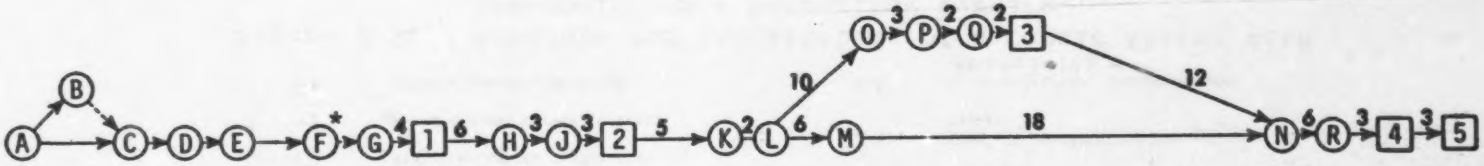
Control Systems - Blast furnace emissions are most commonly controlled by a high-energy wet scrubber. Electric furnaces can use either an open or closed furnace hooding design. In open furnaces all the CO produced burns with induced air at the top of the charge, resulting in a large volume of high-temperature gas. In closed furnaces most or all of the CO is withdrawn from the furnace without combustion with air.

High-energy venturi scrubbers are the most commonly used control devices for both open and closed furnaces. The pressure drop required for high-efficiency particulate collection is about 60 inches water gauge for a ferrosilicon or ferrosilicochrome operation. Substantially all of the sulfur in the reducing agent appears in the gas phase, creating a potential corrosion problem for liquid recycle systems unless neutralizing agents or special materials of construction are used.

Fabric filters can also operate effectively provided the gas temperature is reduced below 500°F. In silica fume collection, however, a buildup of electrostatic charge leads to a high residual pressure drop across the bags.

Electrostatic precipitators have been used only to a limited extent.

Compliance Schedules - Figures 3-91, 3-92, and 3-93 illustrate expeditious schedules for installing a high-energy wet scrubber system, a fabric filter, and an electrostatic precipitator on ferroalloy furnaces.



* Refer to Chapter 2 for time increments A to G.

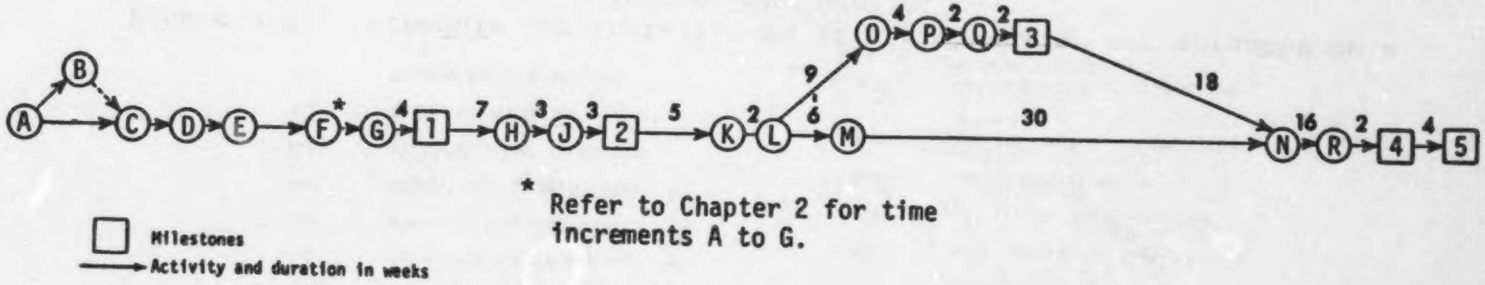
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	40
4	Date by which on-site construction or installation of emission control equipment is completed.	60
5	Date by which final compliance is achieved.	63

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-91. Schedule for installation of a high-energy wet scrubber on a ferroalloy furnace.

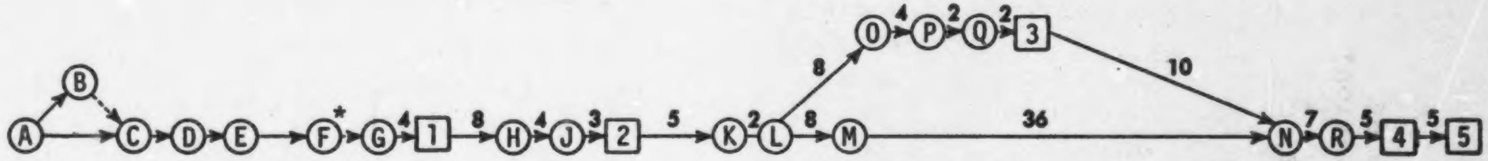


* Refer to Chapter 2 for time increments A to G.

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	17
3	Date of initiation of on-site construction or installation of emission control equipment.	41
4	Date by which on-site construction or installation of emission control equipment is completed.	78
5	Date by which final compliance is achieved.	82

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-92. Schedule for installation of a fabric filter with pre-cooler on a ferroalloy furnace.



* Refer to Chapter 2 for time increments A to G.

□ Milestones
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	42
4	Date by which on-site construction or installation of emission control equipment is completed.	82
5	Date by which final compliance is achieved.	87

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-93. Schedule for installation of an electrostatic precipitator on a ferroalloy furnace.

Sources of Additional Information

Source	Type of information*
1. Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Prepared by Midwest Research Institute for U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. 203 522. May 1971. 613 p.	P, E, C
2. Background Information for Standards of Performance: Electric Submerged Arc Furnaces for Production and Ferroalloys. Volume 1. U.S. Environmental Protection Agency. Publication No. EPA 450/2-74-018A. October 1974.	

*P = Process description
E = Emission rates
C = Control devices

3.6.4 Primary Copper, Lead and Zinc

Process Description - Copper, lead, and zinc are recovered from sulfide ores. Both pyrometallurgical and electrolytic methods are used. Each metal is recovered by oxidizing the sulfide ores, reducing the oxides to a crude metal product, and finally refining the metal. Electrolytic techniques are normally used when high-purity metal is required.

Copper is recovered by four steps: roasting, smelting, converting, and refining. The roasting of copper sulfide ore concentrates is basically a process in which the concentrates are heated in air (or oxygen-enriched air) to the temperature necessary for removing some of the sulfur as sulfur oxides. Multiple hearth and fluid bed roasters are used. Some copper plants charge the ore directly into the reverberatory furnace without roasting.

The roasted product (calcine) is smelted in a reverberatory or electric furnace to produce copper-iron sulfide matte and a silicious slag. This matte is treated in a converter to product blister copper and then sent to a holding furnace for further refining by electrolytic or fire-refining. A flow diagram of primary copper metallurgy is shown in Figure 3-94.

Lead concentrates are first sintered to convert the lead sulfides into oxides, to purify the concentrate by volatilizing some contaminants, to provide a feed with a proper ratio of materials for subsequent smelting operations, and to produce a clinker for blast furnace feed. The blast furnace reduces the lead oxides to metallic lead. From the blast furnace, the bullion is drossed. The dross is sent to a dross reverberatory furnace to recover the lead and the lead bullion is sent to the refining process. Refining requires many steps to remove antimony, tin, arsenic,

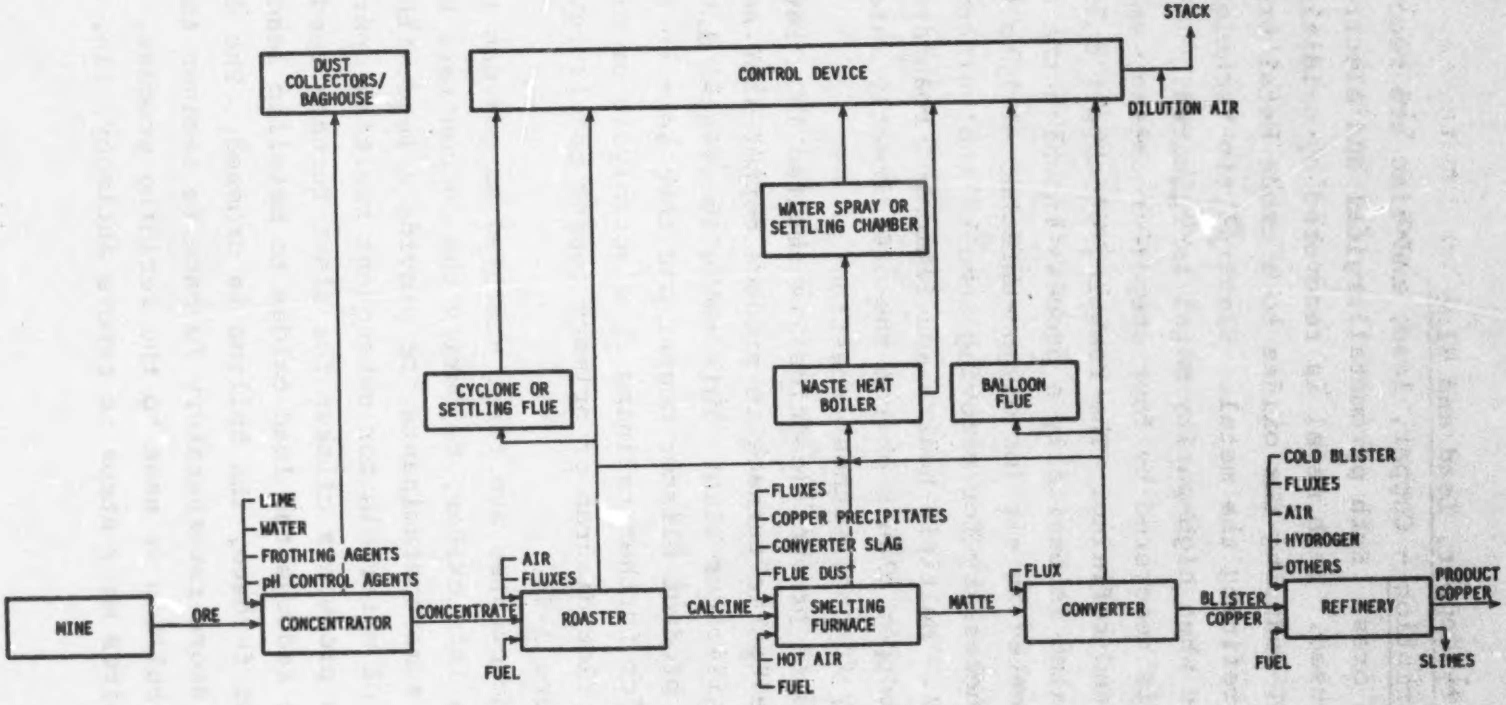

STACK
CONTROL DEVICE
DILUTION AIR
DUST COLLECTORS/ BAGHOUSE
WATER SPRAY OR SETTLING CHAMBER
CYCLONE OR SETTLING FLUE
WASTE HEAT BOILER
BALLOON FLUE
LIME
WATER
FROTHING AGENTS
pH CONTROL AGENTS
AIR
FLUXES
FLUXES
COPPER PRECIPITATES
CONVERTER SLAG
FLUE DUST
FLUX
COLD BLISTER
FLUXES
AIR
HYDROGEN
OTHERS
MINE
ORE
CONCENTRATOR
CONCENTRATE
ROASTER
CALCINE
SMELTING FURNACE
MATTE
CONVERTER
BLISTER COPPER
REFINERY
PRODUCT COPPER
FUEL
HOT AIR
FUEL
FUEL
SLIMES

Figure 3-94. Primary copper smelting flow diagram.

precious metals, zinc, bismuth and other substances. A flow diagram of primary lead smelting is shown in Figure 3-95.

Zinc production is represented in Figure 3-96. The concentrate is first roasted to remove sulfur. Roasting is followed by either pyrometallurgical or electrolytic processing to recover metallic zinc. The first step in pyrometallurgical processing is sintering, which volatilizes lead and cadmium and creates a hard, porous mass for retort furnace feed. In the furnace it is reduced to zinc metal. Three types of retorts are used at primary zinc smelters - horizontal, vertical, and electrothermic. In electrolytic processing, the roasted concentrate is first leached in sulfuric acid to dissolve the zinc, then purified by various filtration and precipitation steps before recovery of metallic zinc by electrolysis.

Atmospheric Emissions - The major pollutants from nonferrous smelting operations are particulate and sulfur dioxide. Emission factors for copper, lead, and zinc smelting are shown in Tables 3-1, 3-2, and 3-3, respectively.

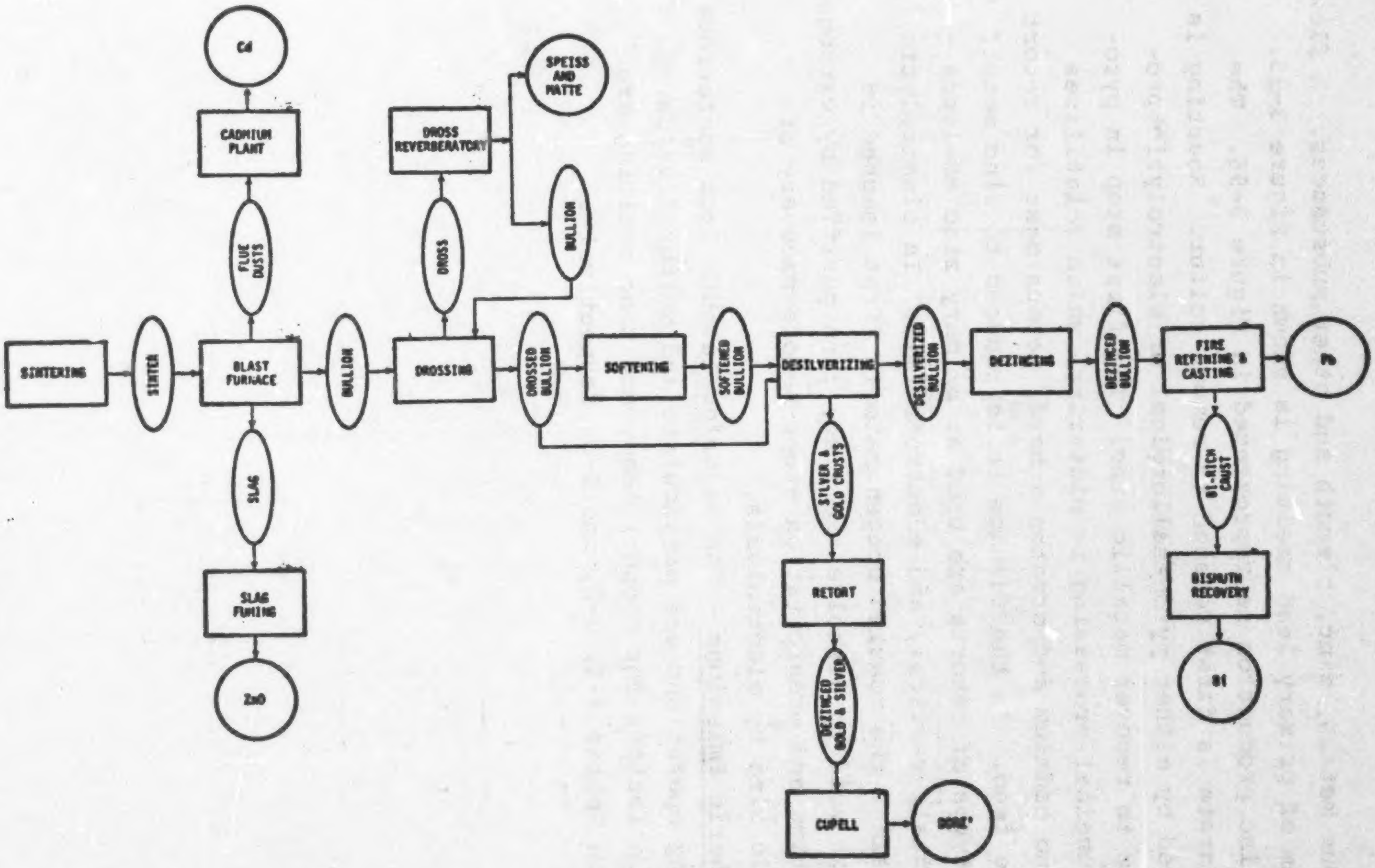

SINTERING
SINTER
BLAST FURNACE
FLUE DUSTS
CADMIUM PLANT
Cd
SLAG
SLAG FUMING
ZnO
BULLION
DROSSING
DROSS
DROSS REVERBERATORY
SPEISS AND MATTE
BULLION
DROSSED BULLION
SOFTENING
SOFTENED BULLION
DESILVERIZING
SILVER & GOLD CRUSTS
RETORT
DEZINCED GOLD & SILVER
CUPELL
DORE'
DESILVERIZED BULLION
DEZINCING
DEZINCED BULLION
FIRE REFINING & CASTING
Pb
BI-RICH CRUST
BISMUTH RECOVERY
Bi

Figure 3-95. Primary lead smelter.[4]

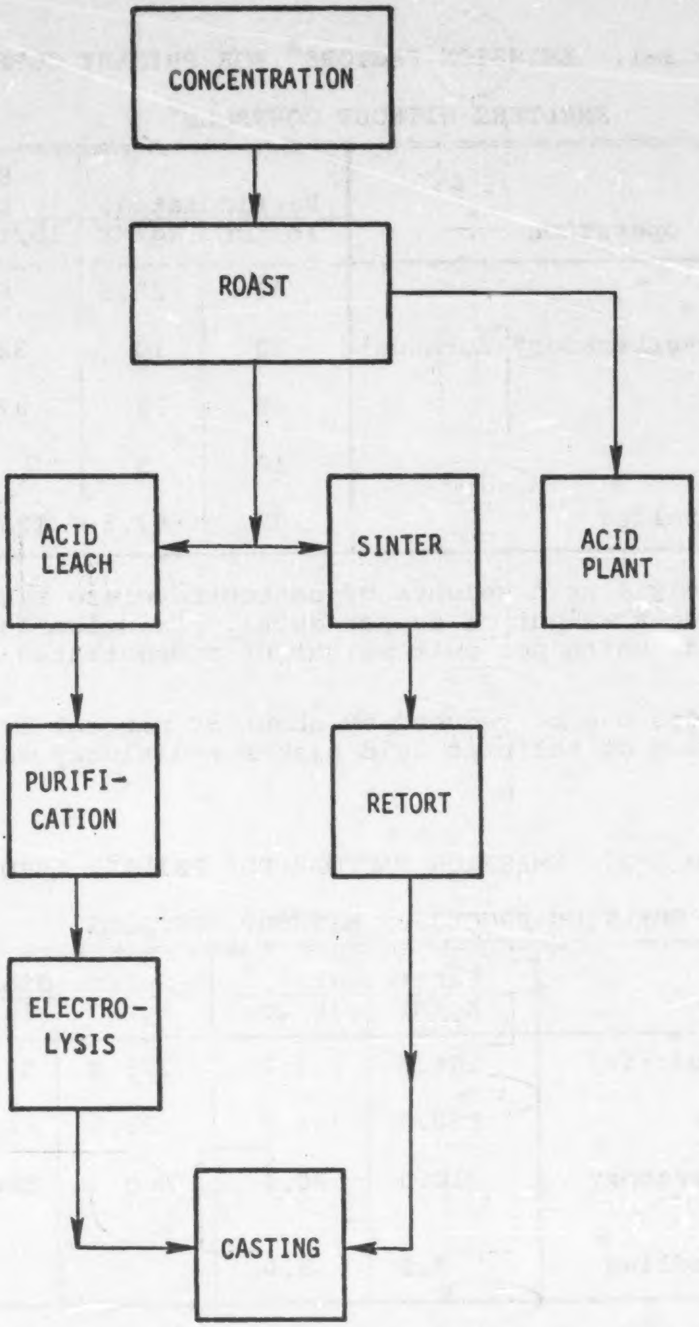

CONCENTRATION
ROAST
ACID LEACH
SINTER
ACID PLANT
PURIFICATION
RETORT
ELECTROLYSIS
CASTING

Figure 3-96. Flow diagram of primary zinc production.

Table 3-1. EMISSION FACTORS[a] FOR PRIMARY COPPER SMELTERS WITHOUT CONTROLS[2]

Type of operation	Particulates,		Sulfur oxides,[b]	
	lb/ton	kg/MT	lb/ton	kg/MT
Roasting	45	22.5	60	30
Smelting (reverberatory furnace)	20	10	320	160
Converting	60	30	870	435
Refining	10	5		
Total uncontrolled	135	67.5	1250	625

[a] Approximately 4 unit weights of concentrate are required to produce 1 unit weight of copper metal. Emission factors expressed as units per unit weight of concentrated ore produced.

[b] Sulfur oxides can be reduced by about 90 percent by using a combination of sulfuric acid plants and slurry scrubbing.

Table 3-2. EMISSION FACTORS FOR PRIMARY LEAD SMELTING PROCESSES WITHOUT CONTROLS[2]

Process	Particulates,[a]		Sulfur dioxide,[a]	
	kg/MT	lb/ton	kg/MT	lb/ton
Sintering (updraft)	106.5	213.0	275.0	550.0
Blast furnace	180.5	361.0	22.5	45.0
Dross reverberatory furnace	10.0	20.0	Neg	Neg
Materials handling	2.5	5.0		

[a] Emission factors expressed as kilograms per metric ton (or pounds per ton) of lead product.

Table 3-3. EMISSION FACTORS[a] FOR PRIMARY ZINC SMELTING WITHOUT CONTROLS[2]

Type of operation	Particulates, lb/ton	Particulates, kg/MT	Sulfur dioxide, lb/ton	Sulfur dioxide, kg/MT
Roasting (multiple-hearth)	120	60	1100	550
Sintering	90	45	b	b
Horizontal retorts	8	4		
Vertical retorts	100	50		
Electrolytic process	3	1.5		

[a] Approximately 2 unit weights of concentrated ore are required to produce 1 unit weight of zinc metal. Emission factors expressed as units per unit weight of concentrated ore produced.

[b] Included in SO_2 losses from roasting.

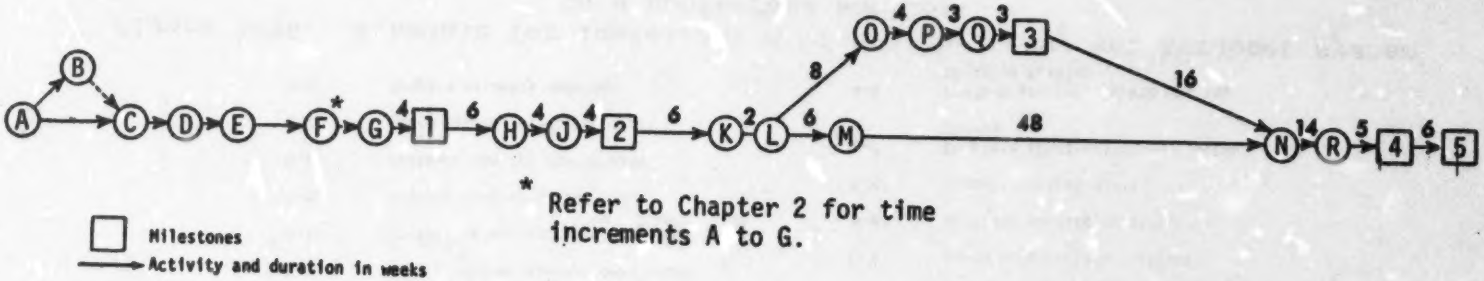
Control Systems - Particulate emissions from nonferrous smelter sources are controlled by electrostatic precipitators, high-energy scrubbers, and fabric filters. Sulfur oxide emissions are generally recovered by use of absorption systems that produce sulfuric acid or elemental sulfur.

The primary copper industry typically uses particulate controls on the roaster, smelting furnace, and converter and sulfur oxide controls on the converter. Fabric filters are not used on roaster effluent because of the corrosiveness of the exit gases and the temperature limitations of the bags. Mechanical collectors and sprays are often used upstream of electrostatic precipitators controlling roaster and furnace emissions to decrease dust loadings and condition the gas. Before the converter gases pass through the absorption system, most of the particulates are removed by high-energy scrubbers, fabric filters, or ESP's.

The primary lead industry normally controls particulates from the sinter machine and drossing furnace by adding an ESP or a fabric filter in series with a mechanical collector. An ESP in series with a centrifugal collector can be used to control blast furnace emissions. Sulfur oxides are collected from sinter plant exhausts by an absorption system following the particulate controls and are converted into sulfuric acid or elemental sulfur.

As in the lead industry, primary zinc smelters collect the SO_2 from the sintering exhaust gases and convert it into sulfuric acid by the contact process. The sinter plant gases must be precleaned by ESP's, fabric filters, or high-energy scrubbers. Roasting and vertical hearth reduction processes are controlled by particulate control systems. Horizontal retorts are not controlled.

Compliance Schedules - Because of the similarities of the primary copper, lead, and zinc industries, an expeditious installation schedule for each type of control system would require approximately the same time period regardless of the applicable process or the metal industry. Figures 3-97 through 3-99 show installation schedules for an ESP, a high-energy scrubber, and an acid plant, respectively.



* Refer to Chapter 2 for time increments A to G.

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	18
3	Date of initiation of on-site construction or installation of emission control equipment.	44
4	Date by which on-site construction or installation of emission control equipment is completed.	99
5	Date by which final compliance is achieved.	105

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
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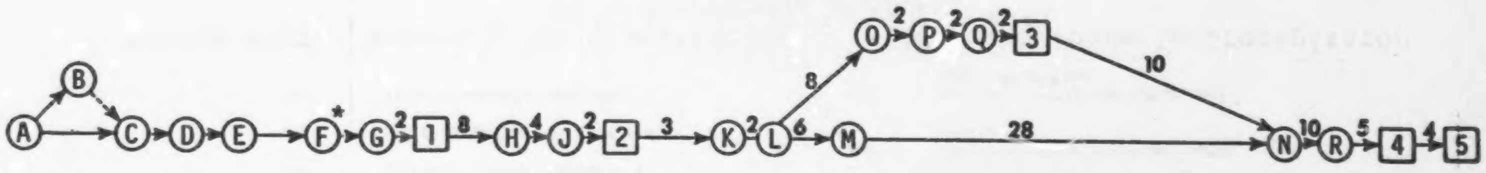
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-97. Schedule for installation of a dry electrostatic precipitator on a nonferrous smelter.



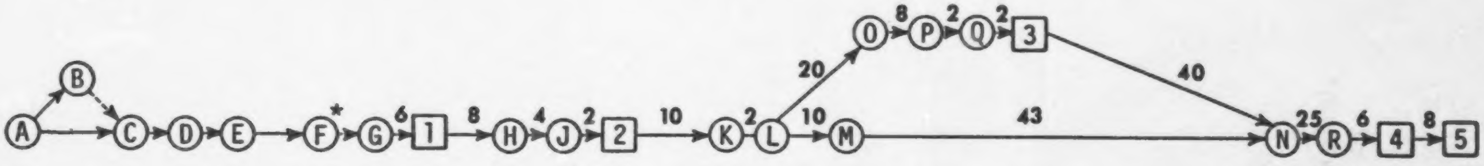
* Refer to Chapter 2 for time increments A to G.

☐ Milestones
→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	35
4	Date by which on-site construction or installation of emission control equipment is completed.	70
5	Date by which final compliance is achieved.	74

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-98. Schedule for installation of a high-energy wet scrubber system on a nonferrous smelter.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	20
3	Date of initiation of on-site construction or installation of emission control equipment.	64
4	Date by which on-site construction or installation of emission control equipment is completed.	135
5	Date by which final compliance is achieved.	143

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-99. Schedule for installation of an acid plant on a primary nonferrous metallurgical process.

Sources of Additional Information

Source	Type of information*
1. Devitt, T.W. et al. Trace Pollutant Emissions from the Processing of Metallic Ores. Prepared by PEDCo-Environmental Specialists, Inc. for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. EPA 650/2-74-115. August 1974.	P, E, C
2. Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication AP-42. February 1976. 462 p.	E
3. Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Prepared by Midwest Research Institute for U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. 203-522. May 1971. pp. 257-281.	P, E, C
4. Control Techniques for Lead Air Emissions. Prepared by PEDCo-Environmental Specialists, Inc. for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. October 1976.	P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.6.5 Iron and Steel

3.6.5.1 Blast Furnace

Process Description - The blast furnace reduces large quantities of iron ore to pig iron by removing impurities and oxygen. Iron-bearing materials (iron ore, sinter pellets, mill scale, open hearth or basic-oxygen-process slag, iron or steel scrap), coke, and fluxes (limestone) are charged into the top of the furnace, and iron is tapped from the bottom.

The heat energy required to effect the required chemical reactions is supplied by reacting coke in the charge with air (preheated to temperatures of 1300 to 1800 °F), which is blown into the bottom of the blast furnace through blowpipes known as "tuyeres". The heat of reaction maintains a pool of molten pig iron (hot metal) in the bottom of the furnace. The high temperature, the limited amount of air, and the presence of large amounts of carbon in the form of coke, produce the desired reducing atmosphere. Carbon monoxide is formed in the high-temperature lower zone and passes up through the solid burden. Excess carbon monoxide (diluted with carbon dioxide, nitrogen, and moisture) passes off the top of the blast furnace and is collected for use as a fuel to heat the air blown into the blast furnace and for other in-plant heating purposes. A typical blast furnace is shown in Figure 3-100.

Periodically the hot metal produced in the blast furnace and the liquid slag (which is a fused mixture of the flux and impurities removed from the ore, pellets, sinter, and coke) are removed from the blast furnace. The hot metal is tapped or "cast", while the slag is said to be "flushed." Hot metal from the furnace flows through troughs into torpedo (submarine) cars for transfer to other steelmaking

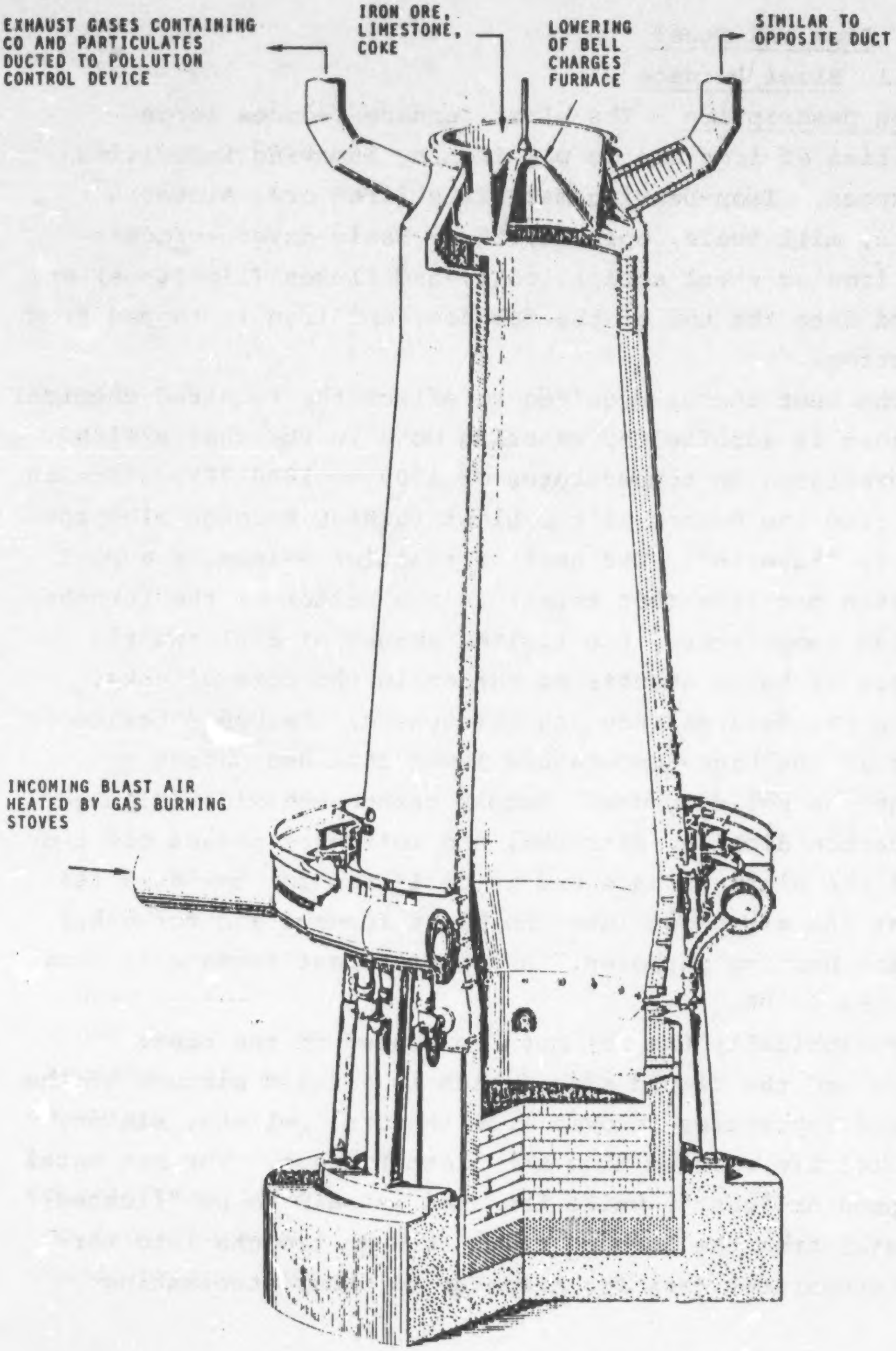

EXHAUST GASES CONTAINING CO AND PARTICULATES DUCTED TO POLLUTION CONTROL DEVICE
IRON ORE, LIMESTONE, COKE
LOWERING OF BELL CHARGES FURNACE
SIMILAR TO OPPOSITE DUCT
INCOMING BLAST AIR HEATED BY GAS BURNING STOVES

Figure 3-100. Typical blast furnace.[3]

processes such as the electric arc or basic oxygen furnace (BOF). Slag flushing is not done during every hot metal tap. When slag builds-up in the furnace it is flushed through the cinder notch by using a water cooled nozzle or "monkey." Since slag floats on the hot metal, the cinder notch is located at a higher elevation than the hot metal tap. The flushed slag is sent through runners to the opposite side of the cast house from the hot metal, and transferred to a dump site or processing area.

Atmospheric Emissions - Particulate emissions from blast furnace stoves are minimal, since a high degree of particulate emission control is utilized to keep the stoves (heat exchangers) from plugging. Without controls, the furnace emits about 150 pounds of particulate per ton of product.[1] Particulate emissions also occur during casting when fumes enter the atmosphere through the open sides of the cast house. Blast furnace slips, which create emissions that bypass the control devices, occur rarely but can cause excessive uncontrolled particulate emissions.[2]

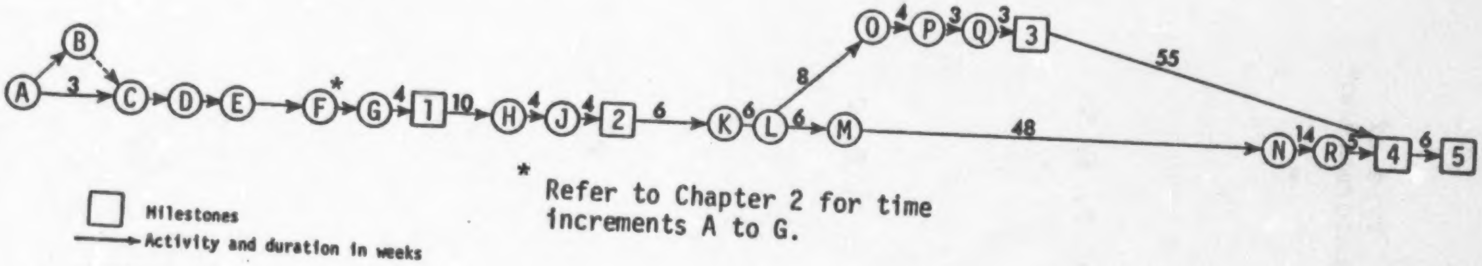
Blast furnace vent gases contain approximately 26 percent carbon monoxide, 16 percent carbon dioxide, and 3 percent hydrogen gas. The heating value of the raw gas is 90 Btu per cubic foot, and the moisture content is about 2 percent by volume.

Most of this gas is used for process heating purposes. The gases leave the furnace at temperatures of 350 to 550°F and at a flow rate of about 90,000 to 23,000 cubic feet per ton of pig iron produced. The actual flow rate of the gases is directly proportional to the coke feed rate.

Control Systems - Cyclones are normally used as precleaners in series with scrubbers and electrostatic precipitators to control blast furnace emissions. Venturi-type wet scrubbers in series with a mechanical collector can reduce exhaust grain loadings to 0.02 grain per cubic foot. In addition to performing a significant gas-cleaning operation, the wet scrubbers condition the gases before they enter an electrostatic precipitator.[3] Since blast furnace gases are used for combustion in steelmaking processes and also to preheat the blast furnace air, the gases are usually cleaned to a high degree and little additional control is required. No specific compliance schedule is therefore provided for blast furnaces. The schedules for a high-pressure-drop scrubber presented in Chapter 2 of this report, could be used.

Cast house emissions can be reduced by total building evacuation through a fabric filter system, or hoods over the tap hole and runners which are vented to fabric filters.

Compliance Schedule - Figure 3-101 shows a schedule for installation of hoods on the tapping and hot metal transfer areas and vented enclosures over the slag pit. The controlling factor in this schedule is the particulate control device, in this case a scrubber or fabric filter.



* Refer to Chapter 2 for time increments A to G.

MILESTONES

		ELAPSED TIME FROM G, WEEKS **
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	22
3	Date of initiation of on-site construction or installation of emission control equipment.	52
4	Date by which on-site construction or installation of emission control equipment is completed.	107
5	Date by which final compliance is achieved.	113

** Total duration in some instances is governed by the delivery time of control device.

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-4	Perform on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-101. Schedule for installation of hoods and ducting to a fabric filter on the cast house of a blast furnace operation.

Sources of Additional Information

	Source	Type of information*
1.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication AP-42. February 1976. pp. 75-1 to 75-6.	E
2.	Katari, V.S. and R.W. Gerstle. Iron and Steel Industry. Prepared by PEDCo-Environmental Specialists, Inc. for U.S. Environmental Protection Agency. Contract No. 68-02-1321, Task No. 26. December 1975. pp. 43-51.	P, E, C
3.	Varga, J., Jr., and H.W. Lownie. System Analysis Study of the Integrated Iron and Steel Industry. Prepared by Battelle Memorial Institute for the National Air Pollution Control Administration, Cincinnati, Ohio. NTIS No. PB 184-577. May 1969. 543 p.	P, E, C
4.	McGannon, H.E., editor. The Making, Shaping, and Treating of Steel, 9th edition. U.S. Steel Company. Pittsburgh, Pennsylvania. 1971.	P

*P = Process description
E = Emission rates
C = Control devices

3.6.5.2 Sinter Plants

Process Description - The sintering process converts the fine material into an agglomerated product that is suitable for blast-furnace feed. The charge consists of iron-bearing raw materials, recycled wastes (such as blast-furnace flue dust, mill scale, and miscellaneous fines), flux (limestone, dolomite, or both), coke breeze or coal, and water. The charge is thoroughly mixed and placed on the sinter strand (a continuous moving grate), and combustion air is drawn through the top of the bed over its active length. The sinter bed is approximately 12 inches thick. The top surface of the material is ignited in a gas-fired or oil-fired combustion furnace. Once the coke breeze is ignited, the combustion is self-supporting to the end of the sinter bed -- the flame front moving down through the bed. The combustion temperature range is 2400 to 2700°F. Typical heat input to the combustion furnace is approximately 150,000 Btu per ton of sinter produced. In order to provide a uniform distribution of combustion air, the sections under the bed are separated into a number of compartments known as windboxes. After the combustion is complete, the sinter cake is often crushed and screened. The undersize is collected in the hot return fines bin for recycling on the strand and the balance is fed to a cooler. Fines from the cooler and the cold screening operation are also recycled. Figure 3-102 shows a simplified schematic diagram of a sintering process.

Atmospheric Emissions - The major air pollutants from sintering are particulates, sulfur dioxide, and carbon monoxide. Hydrocarbons, nitrogen oxide, and in some cases fluorides are emitted in much smaller quantities.

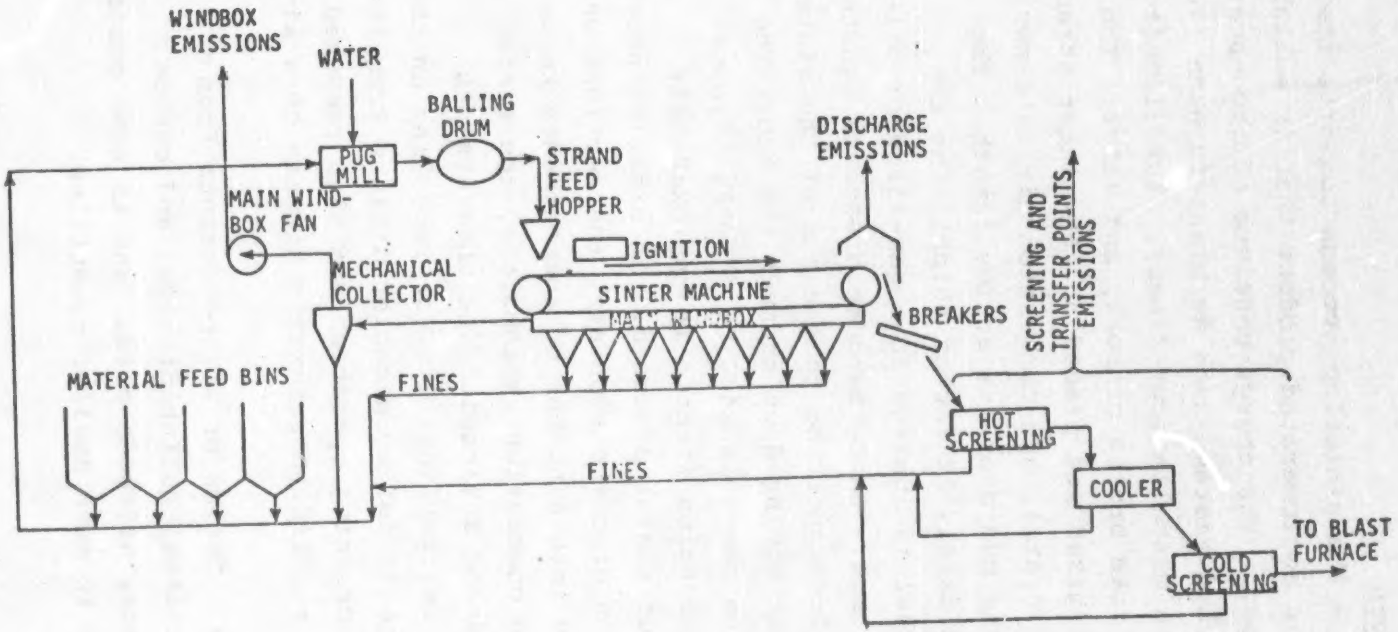

WINDBOX EMISSIONS
WATER
BALLING DRUM
PUG MILL
STRAND FEED HOPPER
MAIN WIND-BOX FAN
IGNITION
MECHANICAL COLLECTOR
SINTER MACHINE
MAIN WINDBOX
DISCHARGE EMISSIONS
BREAKERS
SCREENING AND TRANSFER POINTS EMISSIONS
MATERIAL FEED BINS
FINES
FINES
HOT SCREENING
COOLER
COLD SCREENING
TO BLAST FURNACE

Figure 3-102. Simplified sintering process.

The windbox accounts for approximately half of the total uncontrolled particulate emissions and all of the gaseous emissions from iron and steel sinter plants. Emission factors for windbox emissions are 20, 0.3, and 44 pounds per net ton of sinter product for particulate, SO_2, and CO respectively.[2] A 1975 testing program indicated emission rates of 15, 1.8, and 57 pounds per net ton of sinter produced for particulate, SO_2, and CO, respectively.[1] Emissions of gaseous hydrocarbons and fluorides depend on the chemical composition of the sinter feed; emissions of nitrogen oxides depend on combustion techniques.

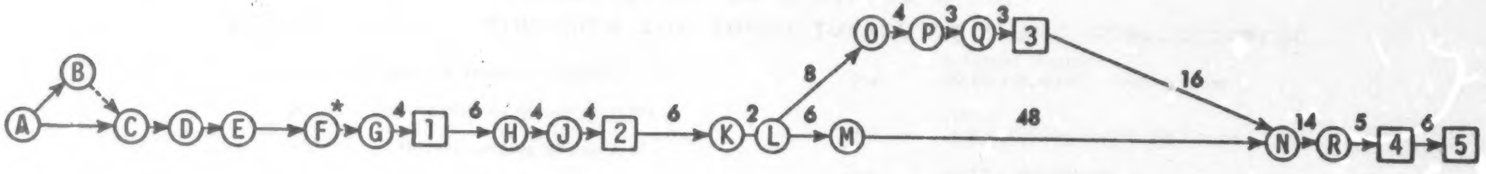
Discharge particulate emissions (after the sinter machine) are generated during sinter breaking, screening, cooling, and conveying operations. These uncontrolled emissions are estimated to be 22 pounds per net ton of sinter produced.

Control Systems - Generally, windbox and discharge particulate emissions are controlled separately. Most plants that effectively control windbox emissions use dry ESP's, high-energy wet scrubbers, or gravel bed scrubbers. Fabric filters and wet ESP's have also been used. All control devices come after mechanical collectors that decrease the dust loading and protect the fan. Emissions from transfer points and discharge (including cooler) emissions are generally controlled by fabric filters, but some plants recycle these exhausts through the strand. When these exhausts are recycled, the windbox control device can be used to control transfer point and discharge particulate emissions. A well-designed control device can provide more than 90 percent particulate control with proper maintenance.

Most sinter plants meet regulations applicable to SO_x and CO emissions without special controls.

Compliance Schedules - Figures 3-103 through 3-106 show expeditious schedules for installation of a dry ESP, a wet ESP, a fabric filter and a high-energy scrubber, respectively. The schedules include the installation of hoods and ducting. Several months may be required for pilot studies before control plans and specifications can be finalized. Studies are needed because of the wide variation in dust characteristics at sinter plants.

The major time increment for all systems is fabrication. The times range from 20 weeks for a fabric filter to 48 weeks for a dry ESP. Total installation times are 109, 89, 56, and 70 for a dry ESP, a wet ESP, a fabric filter, and a high-energy scrubber, respectively.



* Refer to Chapter 2 for time increments A to G.

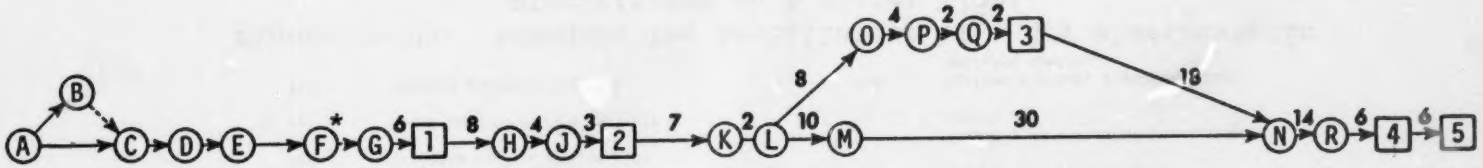
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	18
3	Date of initiation of on-site construction or installation of emission control equipment.	44
4	Date by which on-site construction or installation of emission control equipment is completed.	99
5	Date by which final compliance is achieved.	105

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-103. Schedule for installation of a dry electrostatic precipitator on a sinter plant.



* Refer to Chapter 2 for time increments A to G.

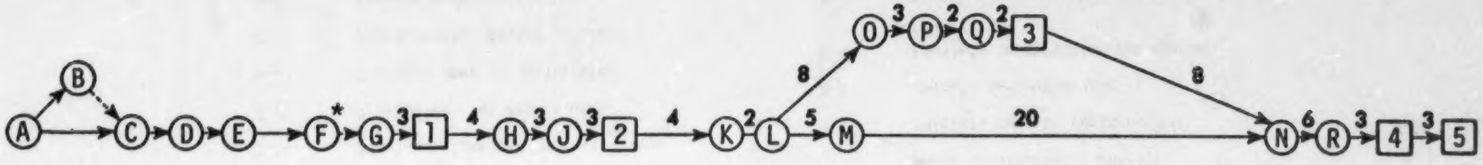
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	21
3	Date of initiation of on-site construction or installation of emission control equipment.	46
4	Date by which on-site construction or installation of emission control equipment is completed.	90
5	Date by which final compliance is achieved.	96

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-104. Schedule for installation of a wet electrostatic precipitator on a sinter plant.



* Refer to Chapter 2 for time increments A to G.

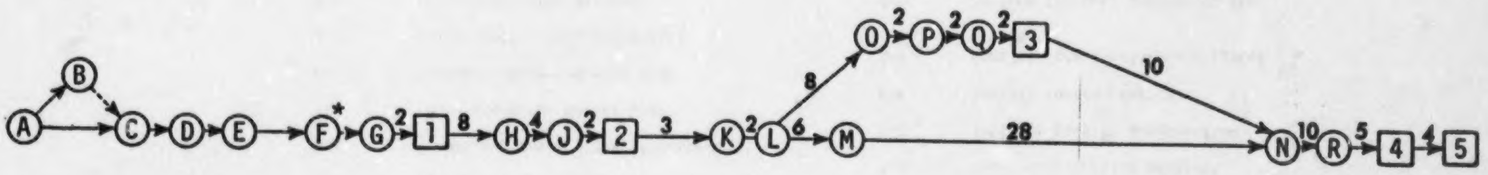
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	13
3	Date of initiation of on-site construction or installation of emission control equipment.	34
4	Date by which on-site construction or installation of emission control equipment is completed.	53
5	Date by which final compliance is achieved.	56

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-105. Schedule for installation of a fabric filter on a sinter plant.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	35
4	Date by which on-site construction or installation of emission control equipment is completed.	70
5	Date by which final compliance is achieved.	74

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-106. Schedule for installation of a high-energy wet scrubber system on a sinter plant.

Sources of Additional Information

	Source	Type of information*
1.	Background Information - Best Systems of Emission Reduction For Sinter Plants In The Iron and Steel Industry. Prepared by PEDCo-Environmental Specialists, Inc., for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Contract No. 68-02-1321, Task No. 10. June 1976.	P, E, C
2.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976.	E
3.	Varga, J., Jr., and H.W. Lownie. A System Analysis of the Integrated Iron and Steel Industry. Prepared by Battelle Memorial Institute for the National Air Pollution Control Administration, Cincinnati, Ohio. NTIS No. PB 184-577. May 1969. 543 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.6.5.3 Open Hearth Furnaces

Process Description - The open hearth furnace is a rectangular unit with a comparatively shallow hearth for containing and processing steel, as shown in Figure 3-107. Scrap, flux, and hot metal are charged into the furnace through several doors in the front of the furnace. The charge materials are heated with various fuels such as oil, tar, natural gas, and combinations of these. Steel is produced by the addition of oxygen to the molten charge to oxidize the carbon, manganese, and silicon contents of the feed. The carbon passes off as carbon monoxide, and the silica and manganese oxides dissolve in the slag. Open hearth steelmaking requires comparatively long time periods, ranging from 8 to 10 hours down to 4 to 5 hours when oxygen lancing is used. Many of these furnaces have been replaced by BOF furnaces, which refine steel more quickly.

Charging and melting of the scrap requires 2 to 4 hours.[1] When melting is complete, the molten contents of the furnace are tapped through ports into the steel ladles. The molten metal is poured into ingot molds of different sizes and shapes. Slag is tapped into slag pots.[2]

Atmospheric Emissions - Emissions from open hearth operations consist mainly of particulates. Fluoride emissions also occur to a much lesser extent. Uncontrolled particulate emissions from a furnace without oxygen lancing are about 8.3 pounds per ton of product; with oxygen lancing, emissions range from 9.4 to 22.0 pounds per ton and average about 17.4 lb/ton. These emissions include minor amounts of gaseous and particulate fluorides.[3] Tests conducted at a major northwest Indiana steel plant showed a particulate concentration of 0.09 grain per cubic foot in stack gas at a flow rate of 26,200 cubic feet per minute.[1]

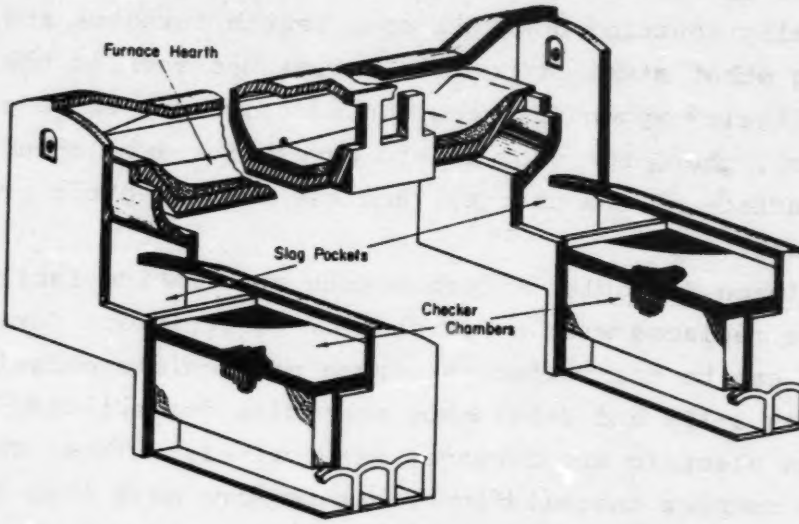
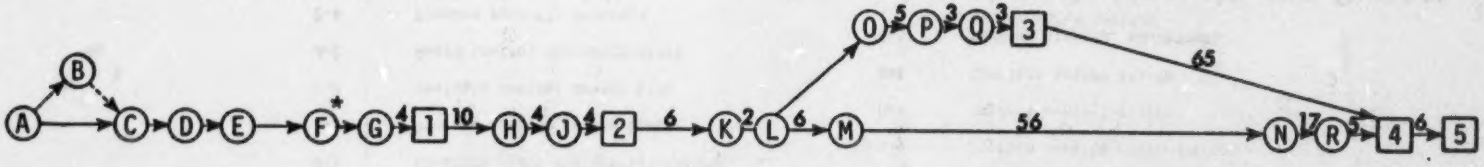

Furnace Hearth
Slag Pockets
Checker Chambers

Figure 3-107. Open hearth furnace.[2]

The flow rates of gases range from 10,600 to 74,000 cubic feet per minute. Gas temperatures range from 460 to 1800°F; the gases must be cooled by waste heat boilers or water sprays before entering any air pollution control equipment.

Control Systems - High-energy wet scrubbers and electrostatic precipitators have been used with some degree of success on open hearth furnaces. The steel industry is gradually shutting down the open hearth furnaces and introducing other steel production techniques such as the BOF shop (basic oxygen furnaces lanced above the surface of the charge), the Q-BOF shop (basic oxygen furnace lanced below the surface of the charge), and the EAF (electric arc furnace).

Compliance Schedules - Open hearth steelmaking facilities may be replaced with a BOF shop or electric arc furnaces, which can be controlled to reduce particulate emissions. Figures 3-108 and 3-109 show schedules for building a BOF and an electric arc furnace, respectively. These are both large complex installations that require more than 2 years to complete. Each of these processes requires a particulate control device such as a high-energy scrubber, electrostatic precipitator, or fabric filter.



* Refer to Chapter 2 for time increments A to G.

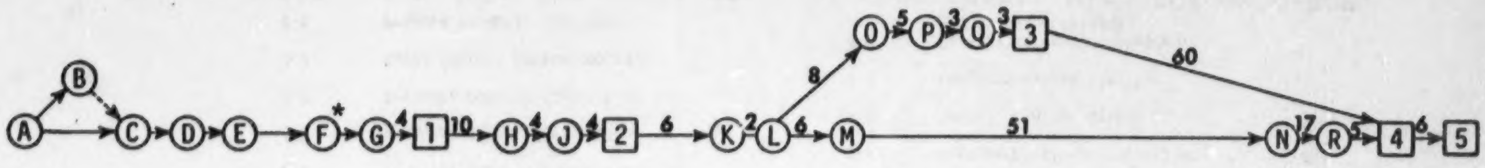
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS	
1	Date of submittal of final control plan to appropriate agency.	4	
2	Date of award of control device contract.	22	
3	Date of initiation of on-site construction or installation of emission control equipment.	49	
4	Date by which on-site construction or installation of emission control equipment is completed.	114	Total duration in some instances is governed by the delivery time of control device.
5	Date by which final compliance is achieved.	120	

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-4	Perform on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-108. Schedule for replacement of open hearth with BOF or Q-BOF.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS	
1	Date of submittal of final control plan to appropriate agency.	4	
2	Date of award of control device contract.	22	
3	Date of initiation of on-site construction or installation of emission control equipment.	49	
4	Date by which on-site construction or installation of emission control equipment is completed.	109	Total duration in some instances is governed by the delivery time of control device.
5	Date by which final compliance is achieved.	115	

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-4	Perform on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-109. Schedule for replacement of open hearth with electric arc furnace.[3]

Sources of Additional Information

	Source	Type of information*
1.	Katari, V.S. and R.W. Gerstle. Iron and Steel Industry. Prepared by PEDCo-Environmental Specialists, Inc., for the U.S. Environmental Protection Agency. Contract No. 68-02-1321, Task No. 26, December 1975. pp. 60-65.	P, E, C
2.	Varga, J., Jr., and H.W. Lownie. System Analysis Study of the Integrated Iron and Steel Industry. Prepared by Battelle Memorial Institute for the National Air Pollution Control Administration, Cincinnati, Ohio. NTIS No. PB 184-577. May 1969. 543 p.	P, E, C
3.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. pp. 75-1 to 75-6.	E
4.	McGannon, H.E., editor. The Making, Shaping, and Treating of Steel, 9th edition. U.S. Steel Company, Pittsburgh, Pennsylvania, 1971.	P

*P = Process description
E = Emission rates
C = Control devices

3.6.5.4 Basic Oxygen Furnace

Process Description - The basic oxygen furnace (BOF) is a pear-shaped vessel containing the charge materials required to make steel. The major materials are hot metal and scrap. In the basic oxygen process, no external heat is supplied to reduce the carbon, silicon, and manganese contents. Oxygen is blown onto the surface of the molten charge through a probe, or in a Q-BOF, is blown under the surface of the melt. The heat generated by oxidation of the elements is sufficient to carry the process to completion. Flux (usually lime) is charged into the vessel to form a slag by combining with the oxides of iron, silicon, and manganese, and to reduce the contents of sulfur and phosphorus in the steel to acceptable limits. A typical BOF is shown in Figure 3-110.

Operating time per melt is approximately 50 minutes. Refining occurs at approximately 3600°F at atmospheric pressure.[1] The steel is tapped into a ladle and alloying materials are added. The slag is tapped into slag pots. Overhead cranes then move the ladle to a line of empty ingot molds (teeming aisle), while the slag pot is moved to the dump yard.[2]

Atmospheric Emissions - About 51 pounds of particulate and about 0.2 pound of gaseous fluorides are produced per ton of BOF product.[3]

Basic oxygen furnaces also cause emission of a flaky black material called "kish," which forms spontaneously whenever hot metal with carbon content greater than 4.5 percent is cooled below its liquid temperature. This results in the formation of solid Fe_3C, which is unstable and decomposes into graphite and iron. Usually the kish is formed when the hot metal is transferred to and from the ladle.[3]

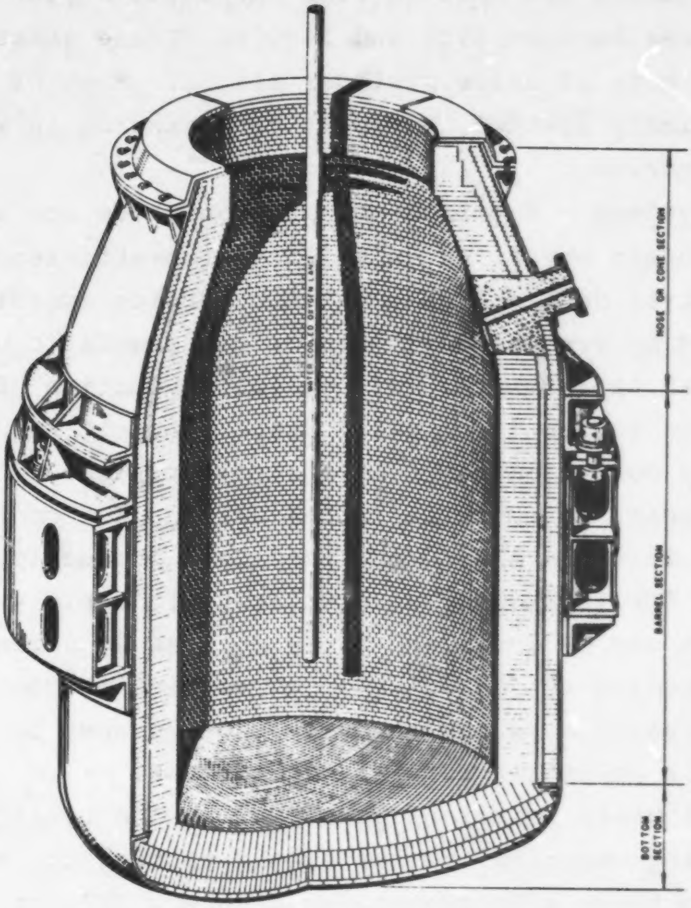

WATER COOLED OXYGEN LANCE
NOSE OR CONE SECTION
BARREL SECTION
BOTTOM SECTION

Figure 3-110. Basic oxygen furnace.[4]

Gas effluents ranging from 200,000 to 1,200,000 cubic foot per minute are emitted from the basic oxygen furnace at temperatures between 2900 and 3450°F. These gases carry 300 pounds or more of oxide dust per minute. Most of the dust is very finely divided, the particles ranging in size from 0.1 to 1 micron.

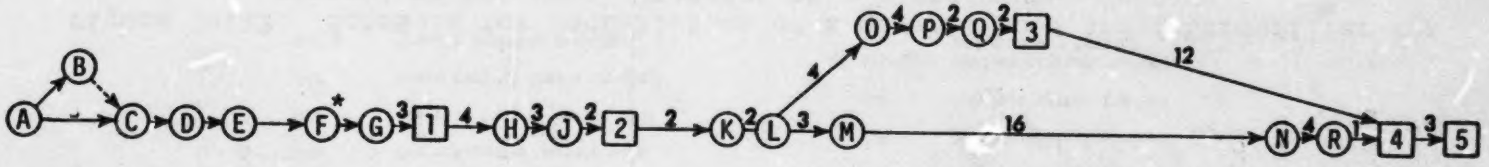
Control Systems - Particulate emission rates are so high that all basic oxygen units utilize high-efficiency particulate control devices. Most of the furnace emissions are controlled by venturi scrubbers or electrostatic precipitators with approximately 98 percent collection efficiency.[3] About 40 to 60 pounds of particulate (largely Fe_2O_3) is ordinarily collected per ton of steel produced.[3]

A significant problem in the design of a control system for a BOF installation is the potential production rate of the BOF. BOF technology is developing so rapidly that production can be increased by as much as 20 percent, sometimes exceeding the capacity of the pollution control equipment. Existing scrubbers and ESP's often must be upgraded to meet air pollution control regulations.

Particulate emissions generated in the transfer of hot metal during charging, re-ladle, and tapping can be controlled by venting these processes to a scrubber, ESP, or fabric filter. Use of these controls would require the design and installation of hoods and ducts to collect the emissions.

Compliance Schedule - Figures 3-111 through 3-113 show schedules for installation of control equipment for furnace charging, hot metal transfer, and furnace tapping, respectively. The controlling factor in many steps is related to the fabric filter.

Tapping emissions can be reduced by use of a control system similar to that used for charging, except that a



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

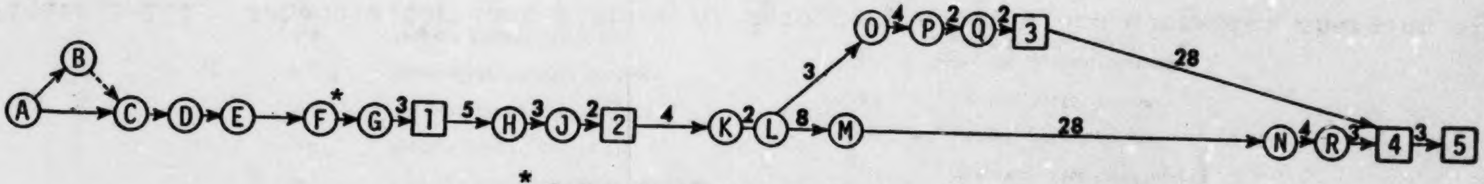
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS	
1	Date of submittal of final control plan to appropriate agency.	3	
2	Date of award of control device contract.	12	
3	Date of initiation of on-site construction or installation of emission control equipment.	28	
4	Date by which on-site construction or installation of emission control equipment is completed.	40	Total duration in some instances is governed by the delivery time of control device.
5	Date by which final compliance is achieved.	43	

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-4	Perform on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-111. Schedule for installation of secondary hooding and ducts for charging of a basic oxygen furnace.

(The schedule is for secondary hooding and ducts only. The controlling factor for installation is the particulate recovery system.)



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

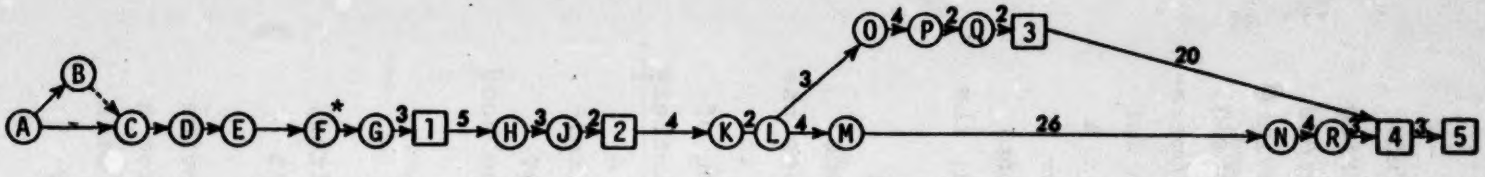
→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	13
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	62
5	Date by which final compliance is achieved.	65

Total duration in some instances is governed by the delivery time of control device.

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-4	Perform on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-112. Schedule for installation of a movable hood and fabric filter for control of hot metal transfer at a basic oxygen furnace.[1]



* Refer to Chapter 2 for time increments A to G.

☐ Milestones
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS	
1	Date of submittal of final control plan to appropriate agency.	3	
2	Date of award of control device contract.	13	
3	Date of initiation of on-site construction or installation of emission control equipment.	30	
4	Date by which on-site construction or installation of emission control equipment is completed.	56	Total duration in some instances is governed by the delivery time of control device.
5	Date by which final compliance is achieved.	59	

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-4	Perform on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-113. Schedule for installation of a secondary hood to new fabric filters for control of tapping of a basic oxygen furnace.

larger hood system and greater exhaust flow are required. Since the furnace tilts away from the charging side during tapping, a separate fume enclosure system must be provided. Many variations of ducting, fans, and final control devices are available for control of these fumes. In some systems, a single device controls both the furnace and tapping operations.[5] A schedule for the basic hood and duct system for control of tapping emissions is shown in Figure 3-113. A fabric filter control device in this system is the controlling factor in the overall schedule. If an existing control device has sufficient capacity and can be used, the schedule can be reduced to about 43 weeks.

The charging control system shown in Figure 3-111 utilizes an auxiliary or secondary hood over the furnace opening when it is tilted forward for charging. Because the hood must be high enough to clear the ladle, it draws in large amounts of room air with the fumes. Installation of the hooding system with fan and motor requires approximately 43 weeks. A control device installation schedule for a large fabric filter or scrubber would thus be the controlling factor, as described in Section 2. If an existing particulate control device has sufficient capacity, the hood exhaust could be ducted into that device.

Transfer of hot metal from the torpedo car to the charging ladle causes emission of fumes, which can be contained in a hood and exhausted through a fabric filter. Installation of such a system requires approximately 65 weeks, as shown in Figure 3-112.

Schedules for upgrading of an existing control device cannot be estimated since they vary widely, ranging from a few months to times similar to those for installation of a new device. The amount of upgrading required directly affects the schedule.

Sources of Additional Information

	Source	Type of information*
1.	Katari, V.S. and R.W. Gerstle. Iron and Steel Industry. Prepared by PEDCo-Environmental Specialists, Inc., for U.S. Environmental Protection Agency. Contract No. 68-02-1321, Task No. 26. December 1975. pp. 66-72.	P, E, C
2.	McGannon, H.E., editor. The Making, Shaping, and Treating of Steel, 9th Edition. U.S. Steel Company, Pittsburgh, Pennsylvania. 1971. pp. 473-497.	P
3.	Compilation of Air Pollutant Emission Factors, 2nd edition. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. pp. 7.5-1 to 7.5-6.	E
4.	Varga, J., Jr., and H.W. Lownie. A System Analysis Study of the Integrated Iron and Steel Industry. Prepared by Battelle Memorial Institute for the National Air Pollution Control Administration, Cincinnati, Ohio. NTIS No. PB 184-577. May 1969. 543 p.	P, E, C
5.	Gas Cleaning and Air Pollution Control for Iron and Steel Processes. Iron and Steel Engineer. 53(6):25-32, 1976.	P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.6.5.5 Electric Arc Furnace

Process Description - Electric furnaces are used to produce both high-alloy and mild steels. In this operation, the heat required to produce steel is supplied as electrical energy. Hot metal from the blast furnace may also be used as part of the charge in some large electric furnaces. An electric arc furnace is shown in Figure 3-114.

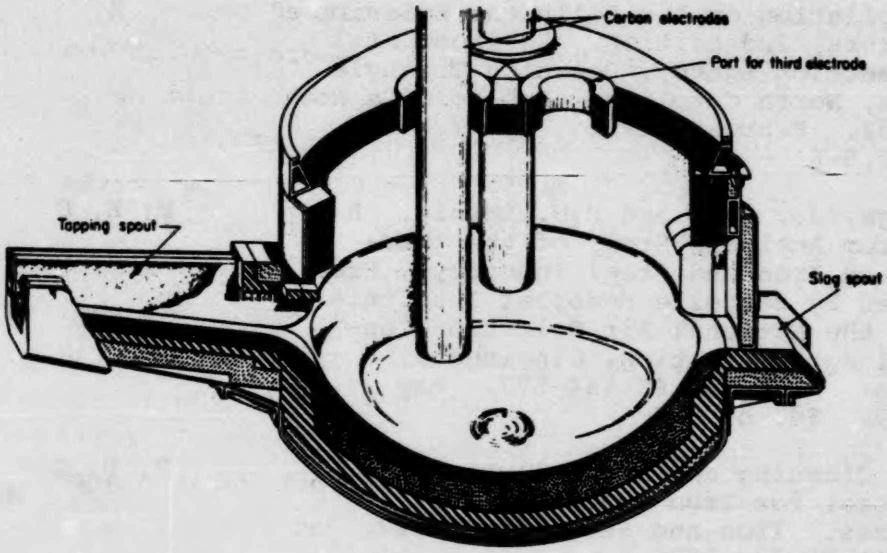

Carbon electrodes
Port for third electrode
Tapping spout
Slag spout

Figure 3-114. Direct-arc electric furnace.[1]

Bucket cranes move raw materials and alloying materials into the furnace. Practically all modern arc furnaces for steelmaking are top-charged. At the time of charging, the electrodes are lifted and moved out of the way. After charging of the metal, scrap, alloys, and fluxes, the electrodes are lowered to about 2 to 3 inches above the charge. As current is applied through the electrodes, the charge is melted and oxidation begins. During this period phosphorus, silicon, manganese, carbon, and other materials are oxidized to form a slag. Oxygen lancing is often used to decrease refining time. At the end of the melt, the electrodes are raised. The tap hole is then opened and the furnace is tilted so that the steel can be tapped from the furnace into a ladle. The slag may be tapped before, during, or after tapping of the steel. A crane moves the ladle either to a pouring platform, where the steel is poured into molds, or to a vacuum-degassing station.[1]

Atmospheric Emissions - Particulate emissions from electric furnaces consist primarily of oxides of iron, manganese, aluminum, and silicon. Lead emissions may also be significant if the lead content of the scrap is high. The uncontrolled particulate emission rate is approximately 9.2 pounds per ton of metal without oxygen lancing and about 11.0 pounds per ton of metal with oxygen lancing.[2] Particulate fumes also occur during tapping and hot metal charging.

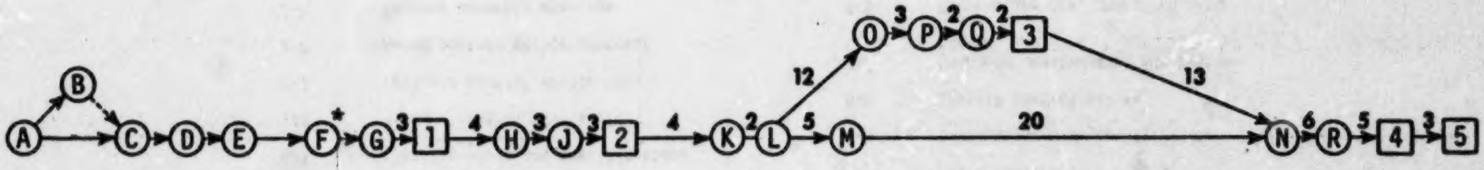
About 18 pounds of carbon monoxide gas is emitted per ton of metal produced.[2]

Control Systems - Gases generated during the meltdown and refining steps are collected by hoods at temperatures ranging from 1200 to 1800°F.[3] These gases are cooled by dilution or quenching before particulate control. Fabric filters have been successfully applied to control of emissions from electric furnaces ranging up to 100 to 150 net tons capacity. Since the design and operating characteristics of electric furnaces can vary widely, development of pollution controls is not straightforward. One of the major problems is design of a hood that will completely capture the fumes. Because most electric-arc furnaces are top-charged, the hood must be removed during charging. As a result, the capture and containment of emissions generated during charging is difficult.

Control of emissions during melting and refining has been done with canopy hoods fitted over each furnace and ducted to a fabric filter. Fugitive emissions such as those from charging and tapping can also be collected by hoods that are ducted to a fabric filter. Another control technique consists of venting the entire building to a fabric filter system.[1]

Compliance Schedules - Figure 3-115 shows a schedule for installation of a fabric filter, hooding, and ductwork to control melting and refining emissions. Figure 3-116 represents a schedule for controlling emissions by evacuation of a whole building to a fabric filter system. The schedules assume the availability of enough space for installation of the control systems. The canopy hood system requires more time because of the engineering and construction involved in fitting a movable hood and duct system around the furnace. The building evacuation system, though much larger, handles warm ambient air and does not involve a hood system. Delivery time for a large motor or fan could extend the building evacuation schedule.

Installation of controls for fugitive emissions from tapping operations would require slightly less time than installation of the furnace control system.



* Refer to Chapter 2 for time increments A to G.

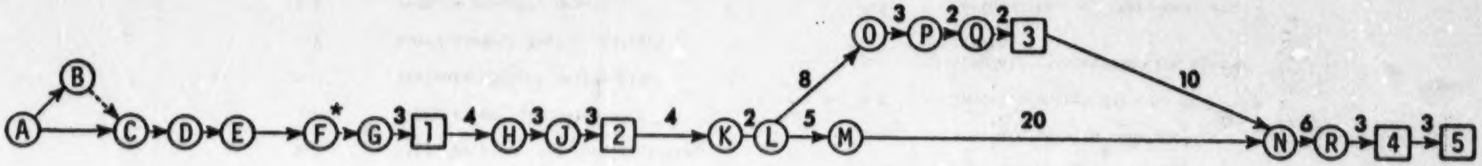
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	13
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	62
5	Date by which final compliance is achieved.	65

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-115. Schedule for installation of canopy hoods and fabric filter on an electric arc furnace.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	13
3	Date of initiation of on-site construction or installation of emission control equipment.	34
4	Date by which on-site construction or installation of emission control equipment is completed.	53
5	Date by which final compliance is achieved.	56

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-116. Schedule for installation of a large fabric filter for building evacuation around an electric arc furnace.

Sources of Additional Information

	Source	Type of information*
1.	Varga, J., Jr., and H.W. Lownie. A System Analysis Study of the Integrated Iron and Steel Industry. Prepared by Battelle Memorial Institute for the National Air Pollution Control Administration, Cincinnati, Ohio. NTIS No. PB 184-577. May 1969. 543 p.	P, E, C
2.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. pp. 7.5-1 to 7.5-6.	E
3.	Katari, V.S. and R.W. Gerstle. Iron and Steel Industry. Prepared by PEDCo-Environmental Specialists, Inc., for U.S. Environmental Protection Agency. Contract No. 68-02-1321, Task No. 26. December 1975. pp. 66-72.	P, E, C
4.	McGannon, H.E., editor. The Making, Shaping, and Treating of Steel, Ninth Edition. U.S. Steel Company, Pittsburgh, Pennsylvania. 1971.	P

*P = Process description
E = Emission rates
C = Control devices

3.6.5.6 Scarfing

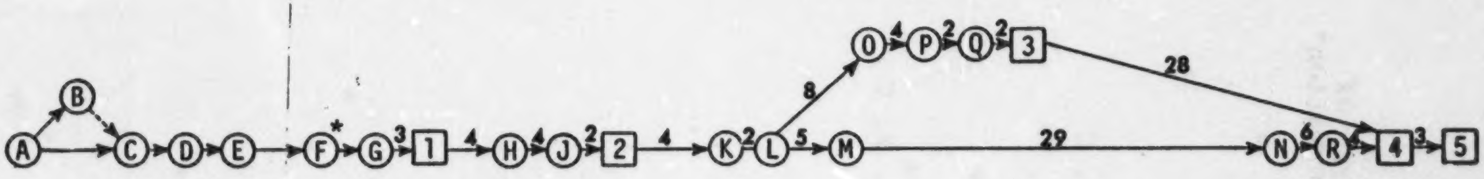
Process Description - Scarfing is the process of removing surface defects from steel slabs and blooms; it is generally done automatically in the rolling mill area. Any additional scarfing is done by hand on cold steel in the conditioning area. Milling machines and grinders are also used to finish the billets.

In this process, oxygen is blown through a tip against the hot steel surface causing rapid oxidation of the surface layer and enough heat to melt and remove the oxidized metal.[1]

Atmospheric Emissions - The scarfing operation generates metal oxide particulates in quantities that vary widely depending on the depth of cut. Maximum particulate emissions are 1 pound per ton of steel produced.

Control Systems - Emissions from automatic scarfing can be controlled by an ESP or scrubber. Collection of the metal oxide particulates in hand-scarfing areas may require numerous hoods. A process change from hand scarfing to grinding with conventional abrasive grinders or chipping with hand-held hammers improves control of emissions.

Compliance Schedules - Figure 3-117 shows a typical schedule for installation of an ESP or scrubber on a scarfing operation. Control device fabrication is the controlling factor, requiring 29 weeks. Total installation time is 66 weeks.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	13
3	Date of initiation of on-site construction or installation of emission control equipment.	35
4	Date by which on-site construction or installation of emission control equipment is completed.	63
5	Date by which final compliance is achieved.	66

Total duration in some instances is governed by the delivery time of control device.

Activity designation	Activity description
A-B	Conduct source tests
A-C	Perform preliminary investigation
C-D	Evaluate control alternatives
D-E	Commit funds for total program
E-F	Prepare control plan and compliance schedule for agency
F-G	Agency reviews and approves plans
G-1	Finalize plans and specifications
1-H	Procure control device bids
H-J	Evaluate control device bids
J-2	Award control device contract
2-K	Prepare assembly drawings

Activity designation	Activity description
K-L	Review and approve assembly drawings
L-M	Prepare fabrication drawings
M-N	Fabricate control device
L-O	Prepare engineering drawings
O-P	Procure construction bids
P-Q	Evaluate construction bids
Q-3	Award construction contract
3-4	Perform on-site construction
N-R	Install control device
R-4	Complete system tie-in
4-5	Perform startup, shakedown, and emission testing

Figure 3-117. Schedule for installation of a canopy type swing-away hood and ESP or scrubber on a scarfing operation.

Sources of Additional Information

	Source	Type of information*
1.	McGannon, H.E., editor. The Making, Shaping, and Treating of Steel, Ninth Edition. U.S. Steel Company. Pittsburgh, Pennsylvania. 1971. pp. 721-724.	P
2.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication AP-42. February 1976. pp. 7.5-1 to 7.5-6.	E, C
3.	Varga, J., Jr., and H.W. Lownie. A System Analysis Study of the Integrated Iron and Steel Industry. Prepared by Battelle Memorial Institute for the National Air Pollution Control Administration, Cincinnati, Ohio. NTIS No. PB 184-577. May 1969. 543 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.7 SECONDARY METALLURGICAL PROCESSES

3.7.1 Aluminum

Process Description - Secondary aluminum operations involve remelting of metal alloys to make castings and ingots. Depending on the source of the aluminum, the process may also include removal of impurities in the melt and introduction of alloying metals to obtain desired properties in the casting. Figure 3-118 illustrates a typical secondary aluminum process.

Impurities are usually removed by fluxing, a term applied to any process in which materials are added to the melt to aid in removal of gases, oxides, or other impurities but do not remain in the final product. Alloying is accomplished by adding a compound containing the desired alloying metal. For example, zinc chloride and zinc fluoride can be used to increase the zinc content of aluminum alloys.

Demagging, which reduces the magnesium content of the melt, is usually accomplished by injecting chlorine gas into the molten bath. This process is discussed in Section 3.7.9.

The metal is melted in crucible, reverberatory, and electrical induction furnaces. Crucible furnaces are indirectly heated and are used for melting small quantities, usually less than 1000 pounds. Reverberatory furnaces are directly fired and are used for melting medium and large batches of 2,000 to 20,000 pounds.

Sweat furnaces are commonly used in secondary aluminum operations to separate the aluminum from iron and other metals. Facilities that process borings or turnings from fabricating operations often use gas- or oil-fired furnaces to burn off the cutting oils and grease before the metal is charged into the melting furnace.

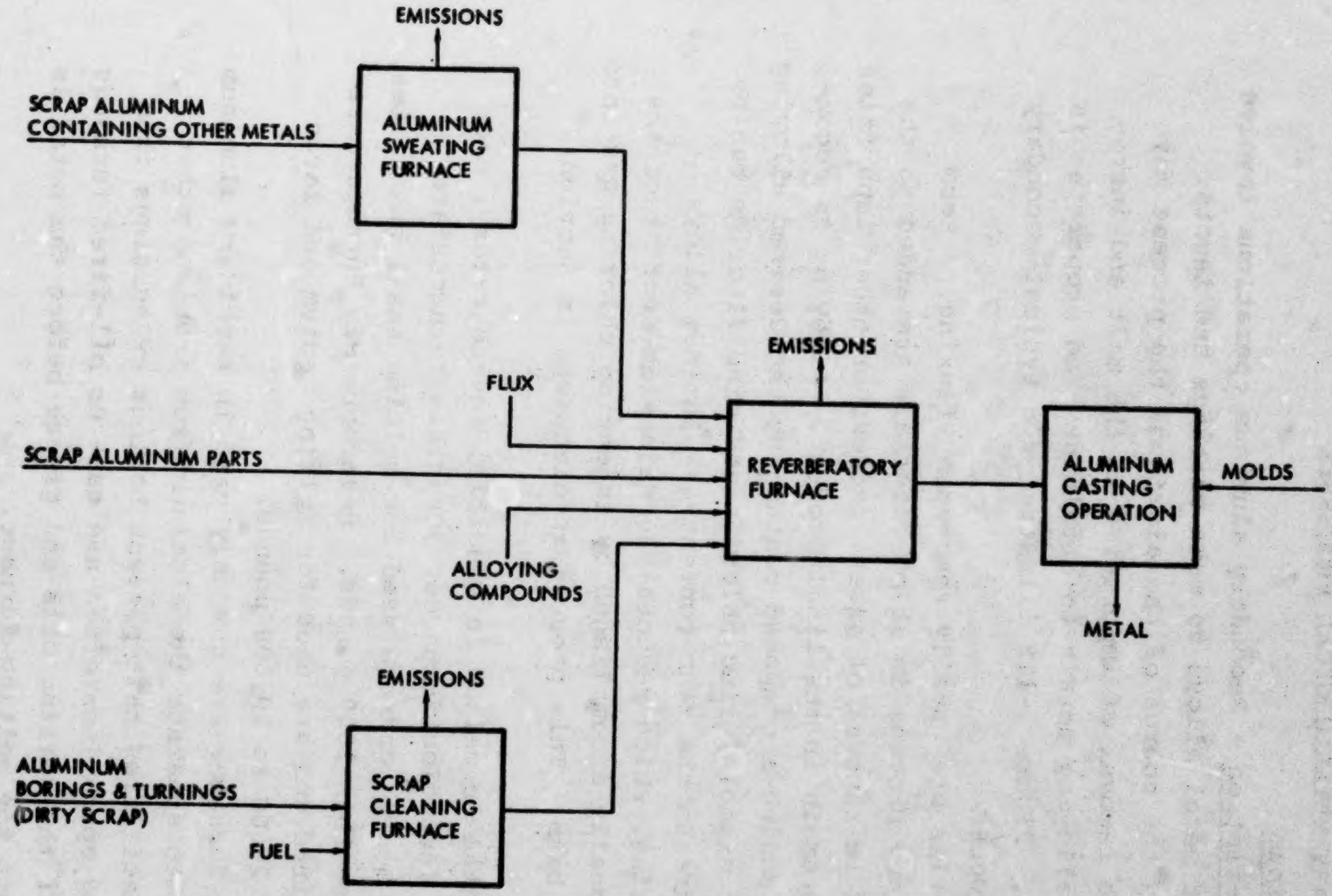

EMISSIONS
SCRAP ALUMINUM CONTAINING OTHER METALS
ALUMINUM SWEATING FURNACE
FLUX
SCRAP ALUMINUM PARTS
EMISSIONS
REVERBERATORY FURNACE
ALUMINUM CASTING OPERATION
MOLDS
ALLOYING COMPOUNDS
METAL
EMISSIONS
ALUMINUM BORINGS & TURNINGS (DIRTY SCRAP)
SCRAP CLEANING FURNACE
FUEL

Figure 3-118. Secondary aluminum process.

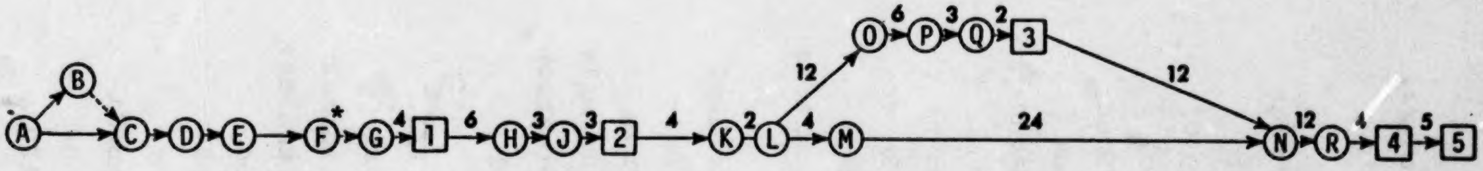
The core making and sand handling systems are integral parts of the foundry. These processes are described in Section 3.7.8.

Atmospheric Emissions - The melting of clean aluminum pigs and foundry returns without the use of fluxes does not create significant atmospheric emissions. The melting of aluminum scrap, however, requires air pollution control equipment to prevent the discharge of excessive emissions, consisting primarily of magnesium and aluminum chloride fumes, which react with moisture in the air to form magnesium and aluminum oxides and hydrogen chloride.

Particulate emissions from the sweat furnaces amount to approximately 15 pounds per ton of metal processed. Reverberatory furnaces emit from 2 to 4 pounds per ton; the chlorination station emits about 1000 pounds of particulates per ton of chlorine consumed (refer to Section 3.7.9).

Control Systems - Fabric filters and wet scrubbers are used to control emissions from reverberatory and crucible furnaces, the fabric filters predominating. An afterburner is also required on sweat furnaces because the effluent is oily and combustible. In a fabric filter/afterburner combination the exhaust gases of the afterburner must be cooled by evaporative or radiant cooling to protect the fabric. Air-to-cloth ratios of the filter bags are approximately 2/1. Dacron^R is a commonly used fabric. High-energy venturi scrubbers require pressure drops as high as 40 to 50 inches water gauge to provide the required collection efficiencies. Switching from a reverberatory furnace to an induction furnace will eliminate products of fuel combustion and minimize emissions caused by oxidation of the aluminum.

Compliance Schedules - Figure 3-119 illustrates an expeditious schedule for installing either a fabric filter or fabric filter/afterburner control system. Figure 3-120



* Refer to Chapter 2 for time increments A to G.

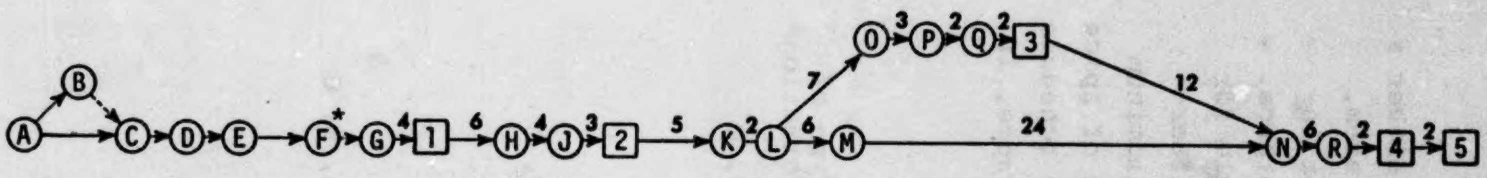
□ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	43
4	Date by which on-site construction or installation of emission control equipment is completed.	73
5	Date by which final compliance is achieved.	78

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-119. Schedule for installation of a fabric filter or fabric filter/afterburner control system on a secondary aluminum process.



* Refer to Chapter 2 for time increments A to G.

□ Milestones
→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	17
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	62
5	Date by which final compliance is achieved.	64

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-120. Schedule for installation of a wet scrubber or wet scrubber/afterburner control system on a secondary aluminum process.

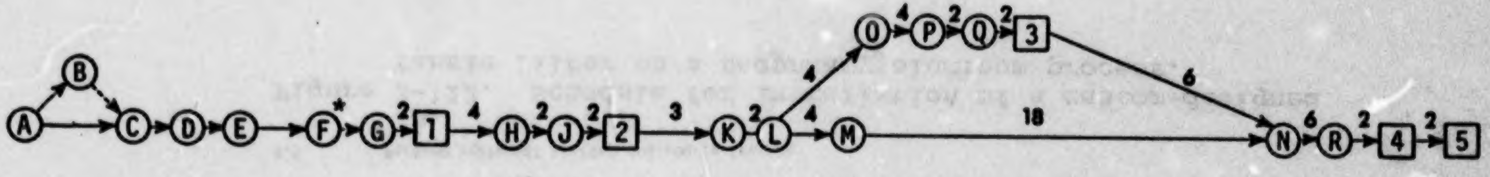
illustrates an expeditious schedule for installing either a wet scrubber or wet scrubber/afterburner control system. Figure 3-121 illustrates an expeditious schedule for installation of an afterburner on a scrap cleaning furnace.

Figure 3-122 illustrates an expeditious schedule for installing a custom-designed baghouse or baghouse/afterburner system to control emissions from secondary aluminum production; such a system might be required because of space limitations or unique process configurations. This schedule can accomodate simultaneous modification of the furnace, if required.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. pp. 283-292.	P, C
2.	Exhaust Gases from Combustion and Industrial Processes. Prepared by Engineering-Science, Inc. for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 204-861. October 1971. 436 p.	P, C
3.	Study of Technical and Cost Information for Gas Cleaning Equipment in the Lime and Secondary Non-Ferrous Metallurgical Industries. Prepared by Industrial Gas Cleaning Institute for the U.S. Environmental Protection Agency. NTIS No. PB 198-137. December 1970.	P, E, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

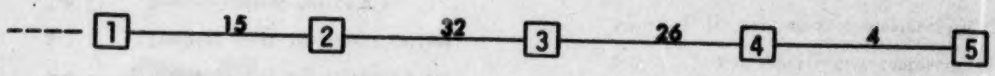
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	27
4	Date by which on-site construction or installation of emission control equipment is completed.	45
5	Date by which final compliance is achieved.	47

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-121. Schedule for installation of an afterburner on a scrap cleaning furnace in aluminum production.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	0
2	Date of award of control device contract.	15
3	Date of initiation of on-site construction or installation of emission control equipment.	47
4	Date by which on-site construction or installation of emission control equipment is completed.	73
5	Date by which final compliance is achieved.	77

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-122. Schedule for installation of a custom-designed fabric filter on a secondary aluminum process.

3.7.2 Brass and Bronze

Process Description - Production of brass and bronze, both copper-based alloys, involves a wide variety of melting, refining, and casting operations. Raw materials in the form of ingots and/or scrap are melted in a furnace, and various fluxes are added to refine the metal. The molten metal is then poured into smaller pots and transferred to the casting area, where it is poured into molds. After the metal cools, the sand mold is separated from the metal in a shake-out area. The casting is then cleaned and processed, and the sand mold material is recycled.

The industry uses a number of melting furnaces, including gas- and oil-fired reverberatory and rotary furnaces and electric induction units. Figure 3-123 illustrates a brass/bronze reverberatory furnace controlled by a fabric filter.

The core making and sand handling systems are integral parts of a brass and bronze foundry. These processes are described in Section 3.7.8.

Atmospheric Emissions - The melting operation represents the primary source of particulate emissions. Particulate composition depends on composition of the metals being melted and the flux materials. Alloys containing zinc, tin, and magnesium tend to produce higher emission levels because of their higher volatility. The quantity of particulate emitted depends primarily on the type of melting furnace. A direct-fired furnace, such as the reverberatory furnace, produces higher emission levels than an indirect-fired unit.

Careful temperature control, proper flux cover, and addition of alloying metals before the melt is started tend to reduce emissions.

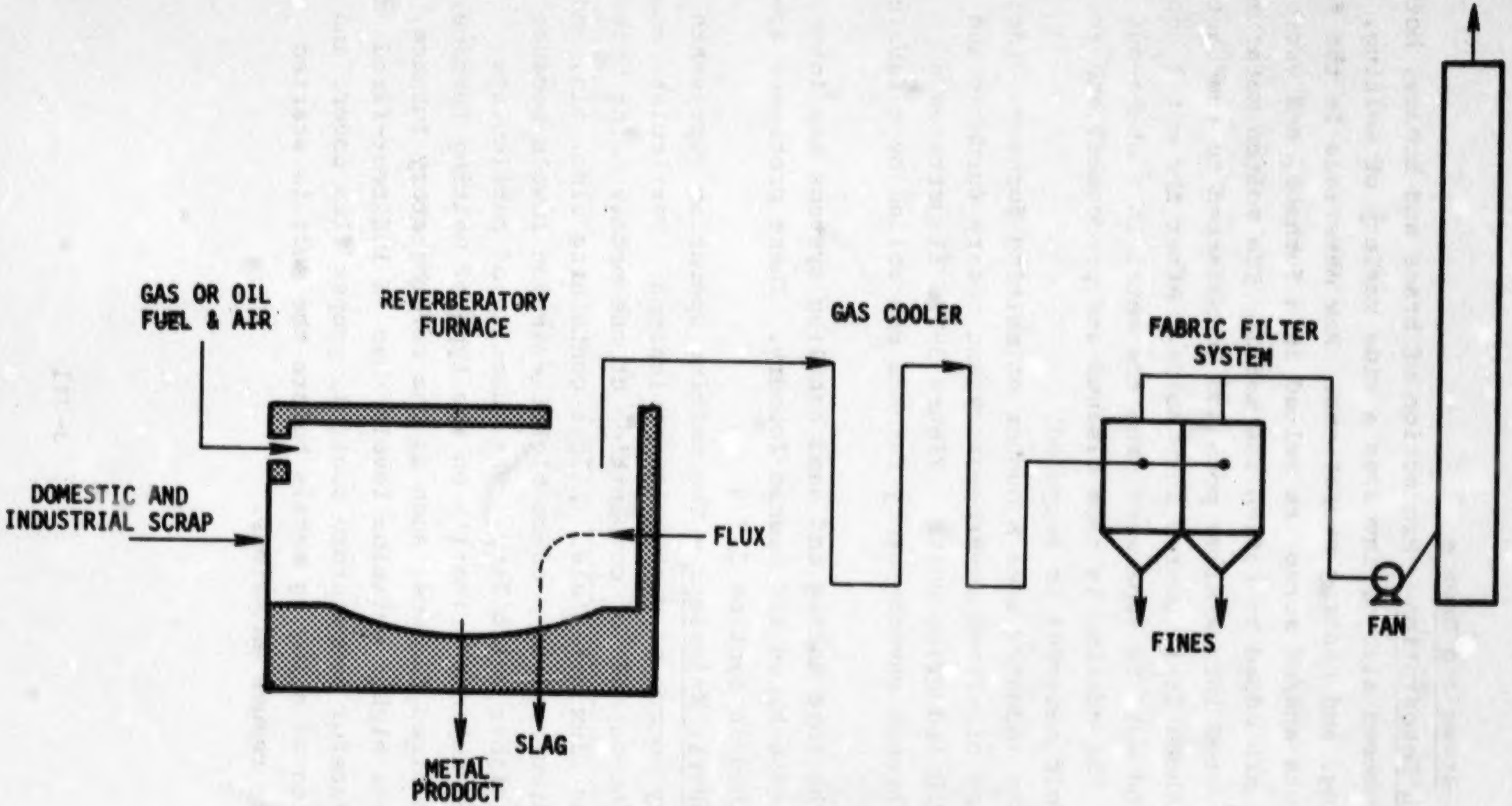

GAS OR OIL FUEL & AIR
REVERBERATORY FURNACE
DOMESTIC AND INDUSTRIAL SCRAP
FLUX
METAL PRODUCT
SLAG
GAS COOLER
FABRIC FILTER SYSTEM
FINES
FAN

Figure 3-123. Brass/bronze reverberatory furnace.

Other sources of particulate emissions include the mold and casting handling and preparation areas. These sources are relatively minor as compared with the furnace emissions.

Control Methods - Process changes and control systems can reduce emissions. The use of crucible or pot furnaces, fired externally with gas or light oil, or the use of electric induction furnaces, can greatly reduce the amount of fume generated in the melting processes.

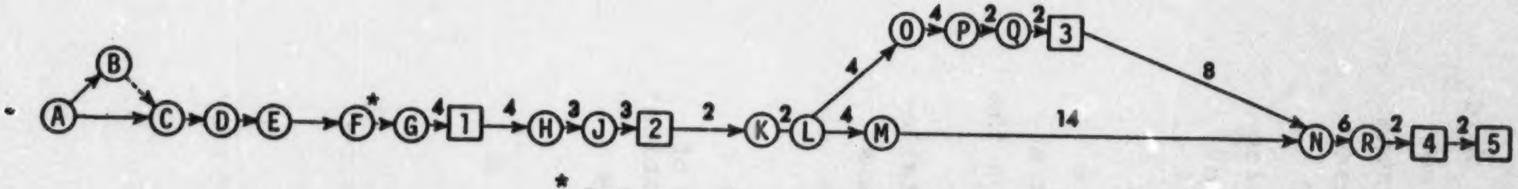
Particulate control is achieved by installation of fabric filter systems. The small particle sizes and the potential presence of hazardous metal compounds require a highly efficient control system. Air-to-cloth ratios on the order of 3/1 are commonly used.

Compliance Schedules - An expeditious schedule for installation of a fabric filter to control emissions from a brass and bronze foundry is shown in Figure 3-124.

Sources of Additional Information

	Source	Type of information*
1.	Air Pollution Aspects of Brass and Bronze Smelting and Refining Industry. National Air Pollution Control Administration, Raleigh, North Carolina. Publication No. AP-68. March 1970. 114 p.	E, C
2.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	46
5	Date by which final compliance is achieved.	48

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-124. Schedule for installation of a fabric filter on a brass and bronze foundry.

3.7.3 Steel

Process Description - Steel foundries differ from basic iron and steel plants in that the primary raw material is scrap steel. The foundries produce cast steel, usually for heavy industrial uses, such as bulldozer frames and locomotive wheels.

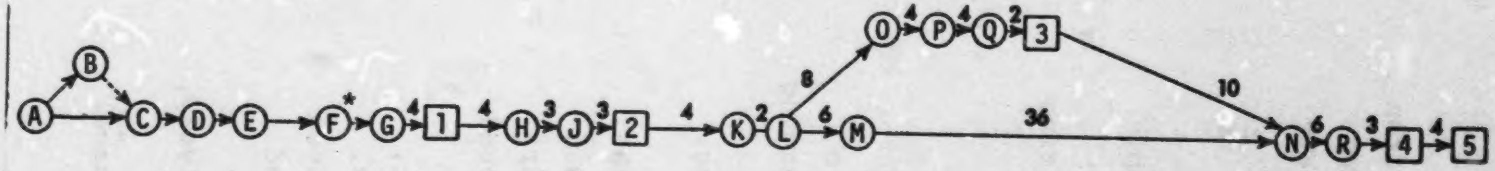
Three types of furnaces are in common use: direct electric-arc, electric induction, and open hearth. Scrap, pig iron, ferroalloys, and limestone are charged to the furnace. Refined steel is produced in the melt by oxidizing the impurities, reducing the iron oxide, and adding the desired alloying constituents.

Atmospheric Emissions - Particulate emissions from steel foundry operations include iron oxide fumes, sand fines, graphite, and metal dust. Hydrocarbon emissions can also occur if dirty scrap is charged. Primary factors influencing the quantity of pollutants emitted are the quality and cleanliness of the scrap and the amount of oxygen lancing.

Particulate emissions from an electric arc furnace range between 4 and 40 pounds per ton, averaging about 13 pounds per ton of metal processed. Emissions from an open-hearth furnace average about 11 pounds of particulate per ton and from an electric induction furnace, about 0.1 pound per ton of metal processed.

Control Systems - Fabric filters and, to a lesser extent, wet scrubbers are the most commonly used control devices. Air-to-cloth ratios for the fabric filter should not exceed 2.5/1. Dacron and glass fiber are the most commonly used fabrics.

Compliance Schedules - Figures 3-125 and 3-126, respectively, illustrate expeditious schedules for installation of a fabric filter and a wet scrubber on a steel foundry furnace.



* Refer to Chapter 2 for time increments A to G.

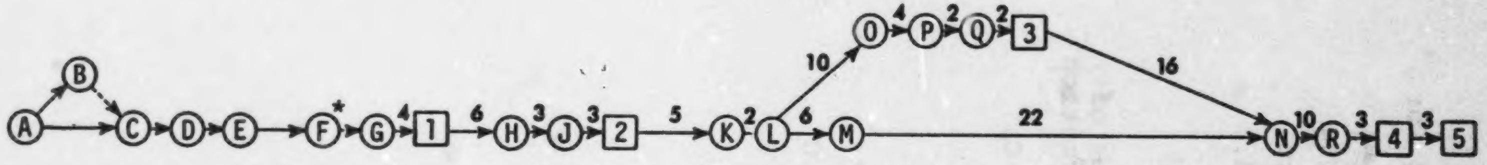
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	71
5	Date by which final compliance is achieved.	75

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-125. Schedule for installation of a fabric filter on a steel foundry furnace.



* Refer to Chapter 2 for time increments A to G.

□ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	41
4	Date by which on-site construction or installation of emission control equipment is completed.	70
5	Date by which final compliance is achieved.	73

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

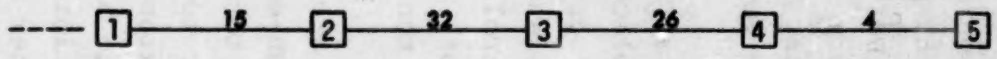
Figure 3-126. Schedule for installation of a wet scrubber on a steel foundry furnace.

Figure 3-127 illustrates an expeditious schedule for installing a custom-designed fabric filter where it is required by such factors as space limitations or unique process configurations. This schedule can accommodate simultaneous modification of the furnace, if required.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, C
2.	Exhaust Gases from Combustion and Industrial Processes. Prepared by Engineering-Science, Inc. for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. 204-861. October 1971. 436 p.	P, C

*P = Process description
E = Emission rates
C = Control devices



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	
2	Date of award of control device contract.	15
3	Date of initiation of on-site construction or installation of emission control equipment.	47
4	Date by which on-site construction or installation of emission control equipment is completed.	73
5	Date by which final compliance is achieved.	77

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-127. Schedule for installation of a custom-designed fabric filter on a steel foundry furnace.

3.7.4 Gray Iron

Process Description - Gray iron foundries produce a heavy, brittle metal commonly called cast iron but also named for its characteristic gray-white color. Three types of furnaces are in common use: cupolas, reverberatory furnaces, and electric induction furnaces. Cupolas, which are used to melt over 90 percent of the metal poured for gray iron castings, range in capacity from 1 to 50 tons of metal per hour. Electric furnaces are gaining in popularity, partially because of their low emission rates. Reverberatory furnaces are used in about 2 percent of the foundries. Figure 3-128 presents a flow diagram for a gray iron foundry process.

Atmospheric Emissions - Emissions from cupolas consist primarily of metallic oxides plus products of incomplete combustion from the oils and grease adhering to the scrap. Carbon monoxide is emitted in significant amounts because the cupola's atmosphere is oxygen-deficient. Uncontrolled emission rates are approximately 15 and 150 pounds of particulates and carbon monoxide, respectively, per ton of metal charged.

Control Systems - Afterburner/fabric filter systems are most commonly used to control emissions. Afterburner/high-energy wet scrubber systems are also used. Gas burners or torches are often installed directly above the charging door to control emissions of carbon monoxide and, to some extent, odors. The afterburner section should be designed to allow a residence time of approximately 0.5 second and a minimum temperature of 1200°F. The gases from the afterburner must be cooled by air dilution, radiant cooling, or quenching with water to protect the fabric filter. Air dilution and radiant cooling are usually preferred since they minimize

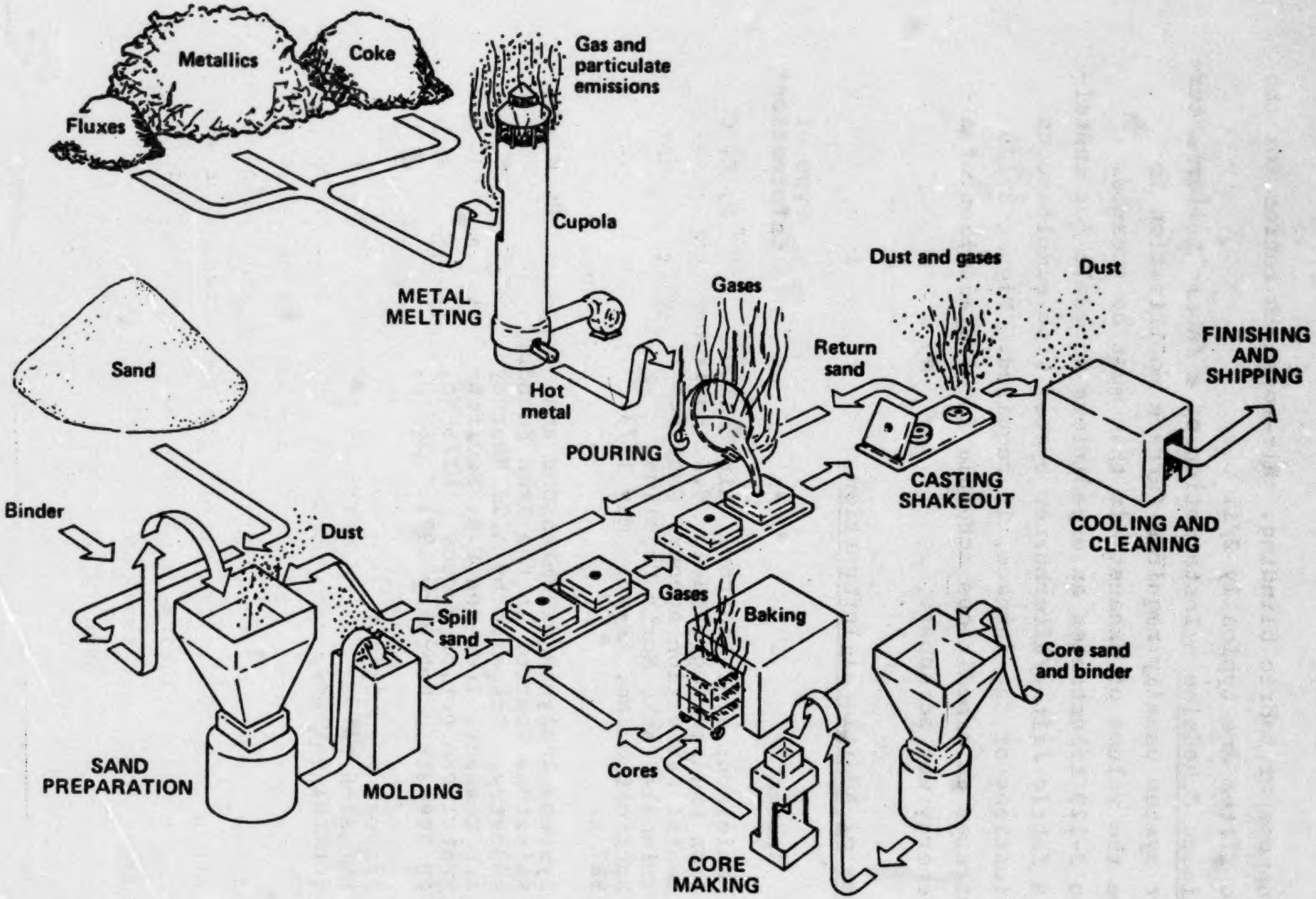

Fluxes
Metallics
Coke
Gas and particulate emissions
Cupola
METAL MELTING
Sand
Hot metal
Gases
Dust and gases
Dust
FINISHING AND SHIPPING
Return sand
POURING
CASTING SHAKEOUT
COOLING AND CLEANING
Binder
Dust
Gases
Baking
Spill sand
Core sand and binder
SAND PREPARATION
MOLDING
Cores
CORE MAKING

Figure 3-128. Gray iron foundry process.

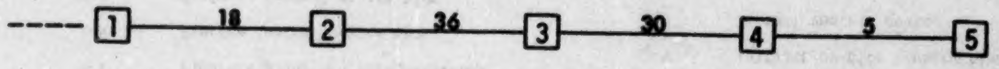
the chances of fabric blinding. Air-to-cloth ratios for the fabric filter are typically 2/1.

Compliance Schedules - Installation of a fabric filter/afterburner system usually requires furnace modification to reduce the volume of exhaust air that must be treated. Figure 3-129 illustrates an expeditious schedule for installing a fabric filter/afterburner system with simultaneous modifications of the furnace, if required. Figure 3-130 illustrates an expeditious schedule for installation of a high-energy wet scrubber.

Sources of Additional Information

Source	Type of information*
1. Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, E, C
2. Systems Analysis of Emissions and Emissions Control in the Iron Foundry Industry. Prepared by A.T. Kearney and Company, Inc. for U.S. Environmental Protection Agency. NTIS No. PB 198-348. February 1971. 368 p.	P, E, C

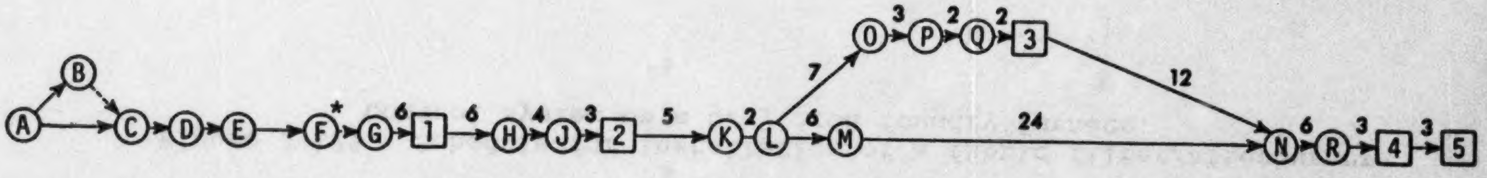
*P = Process description
E = Emission rates
C = Control devices



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	0
2	Date of award of control device contract.	18
3	Date of initiation of on-site construction or installation of emission control equipment.	54
4	Date by which on-site construction or installation of emission control equipment is completed.	84
5	Date by which final compliance is achieved.	89

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-129. Schedule for installation of a fabric filter/afterburner control system on a gray iron foundry furnace.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	40
4	Date by which on-site construction or installation of emission control equipment is completed.	65
5	Date by which final compliance is achieved.	68

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-130. Schedule for installation of a high-energy wet scrubber system on a gray iron foundry furnace.

3.7.5 Lead Smelting

Process Description - Three types of furnace are used to produce the common grade of lead: the pot furnace, the reverberatory furnace, and the blast furnace or cupola.

Pot furnaces, which are indirectly fired, are used primarily for alloying and refining. Reverberatory furnaces are used in the processing of lead scrap metal in several ways, including burnout, sweating, melting, and purification. The burnout operation involves incineration of combustible materials in the scrap, such as plastics, rubber insulation, wood, and paper. In lead sweating operations, lead is separated from a mixture of materials, many having melting points higher than that of lead. The primary use of reverberatory furnaces is for lead melting and purifying the lead by removal of extraneous ingredients. Figure 3-131 illustrates a lead reverberatory furnace controlled by a fabric filter.

The lead cupola is similar to the iron cupola used in ferrous smelting. Unlike the reverberatory furnace, the cupola serves a very specific function: to reduce the oxidized metal. The material charged consists of lead-containing alloys, slag, coke, and limestone, with some scrap cast iron. Additional charges are added at intervals as the material melts down.

The core making and sand handling systems are integral parts of the foundry. These processes are described in Section 3.7.8.

Atmospheric Emissions - Particulate emissions from the crucible furnace are usually less than 1 pound per ton of material charge. Because this material is extremely hazardous, however, the process requires a high degree of control. Particulate emissions from reverberatory and blast

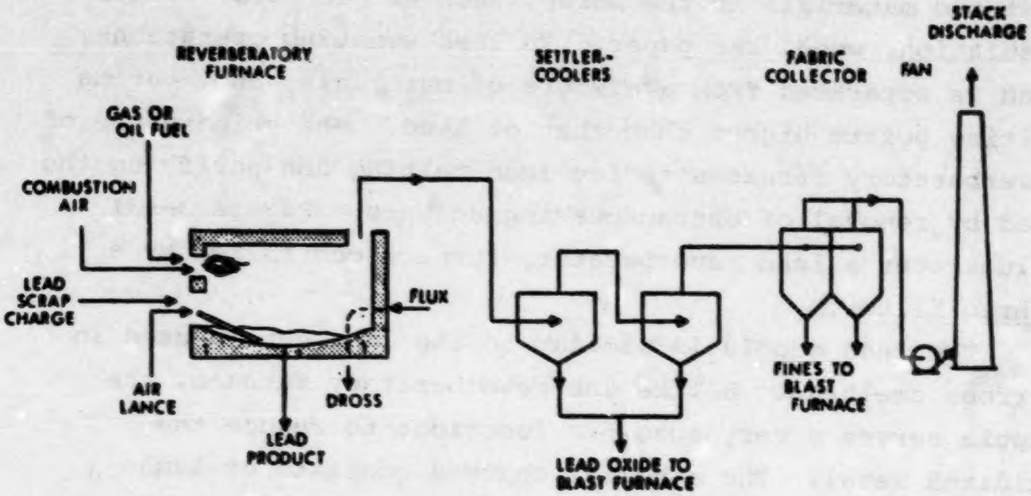

REVERBERATORY FURNACE
GAS OR OIL FUEL
COMBUSTION AIR
LEAD SCRAP CHARGE
AIR LANCE
FLUX
DROSS
LEAD PRODUCT
SETTLER-COOLERS
LEAD OXIDE TO BLAST FURNACE
FABRIC COLLECTOR
FINES TO BLAST FURNACE
FAN
STACK DISCHARGE

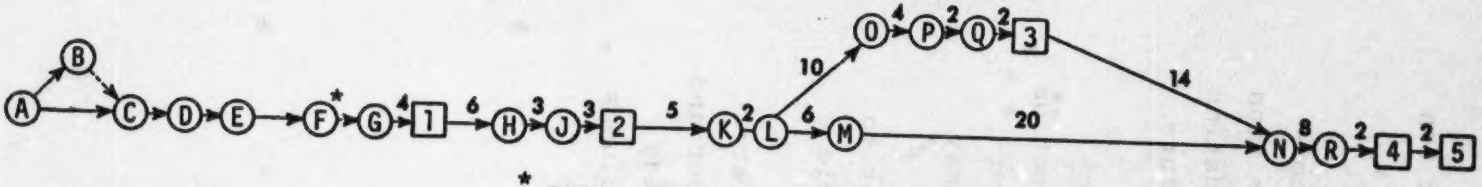
Figure 3-131. Lead reverberatory furnace.

furnaces amount to approximately 130 and 190 pounds per ton of metal processed, respectively.

Although particulates are usually the emission of primary concern, emissions of sulfur oxides, carbon monoxide, hydrocarbons, and hydrogen chloride (from decomposition of chlorine-containing materials) can be caused by oxidation of the sulfur content of the materials charged to the furnace (e.g. lead batteries).

Control Systems - Particulate emissions are usually controlled by fabric filters operating with air-to-cloth ratios of about 2/2. Orlon fabric is frequently used. A reverberatory furnace burning significant amounts of scrap may require an afterburner system to complete combustion, followed by a fabric filter or high-energy wet scrubber to remove particulate; the scrubber can also remove soluble gases.

Compliance Schedules - Figures 3-132 and 3-133 illustrate expeditious schedules for installation of a wet scrubber and a fabric filter system, respectively, on a lead smelting furnace. The schedule for the wet scrubber system includes the time required to install the associated wastewater treatment equipment.



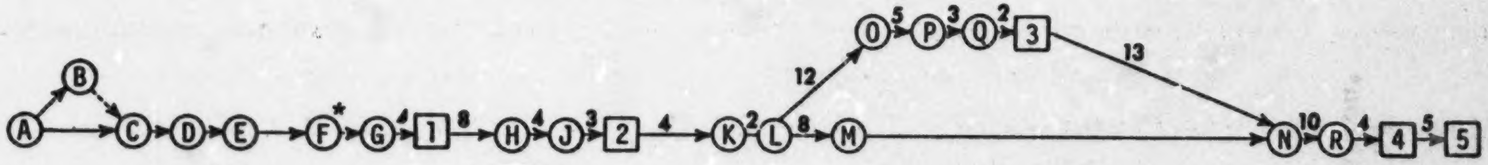
* Refer to Chapter 2 for time increments A to G.

☐ Milestones
→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	41
4	Date by which on-site construction or installation of emission control equipment is completed.	65
5	Date by which final compliance is achieved.	67

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-132. Schedule for installation of a wet scrubber system on a lead smelting furnace.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	47
4	Date by which on-site construction or installation of emission control equipment is completed.	75
5	Date by which final compliance is achieved.	80

Activity designation	Activity description
A-B	Conduct source tests
A-C	Perform preliminary investigation
C-D	Evaluate control alternatives
D-E	Commit funds for total program
E-F	Prepare control plan and compliance schedule for agency
F-G	Agency reviews and approves plans
G-1	Finalize plans and specifications
1-H	Procure control device bids
H-J	Evaluate control device bids
J-2	Award control device contract
2-K	Prepare assembly drawings
K-L	Review and approve assembly drawings
L-M	Prepare fabrication drawings
M-N	Fabricate control device
L-O	Prepare engineering drawings
O-P	Procure construction bids
P-Q	Evaluate construction bids
Q-3	Award construction contract
3-N	Initiate on-site construction
N-R	Install control device
R-4	Complete construction and system tie-in
4-5	Perform startup, shakedown, and emission testing

Figure 3-133. Schedule for installation of an afterburner/baghouse system on lead smelting furnace.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, C
2.	Study of Technical and Cost Information for Gas Cleaning Equipment in the Lime and Secondary Non-Ferrous Metallurgical Industries. Prepared by the Industrial Gas Cleaning Institute for the U.S. Environmental Protection Agency. NTIS No. PB 198-137. December 1970. 307 p.	P, E, C

*
P = Process description
E = Emission rates
C = Control devices

3.7.6 Zinc Smelting

Process Description - Secondary zinc for use in alloying, casting, and galvanizing is made from ingots, rejected castings, and scrap. Melting is done in a variety of furnaces, including crucible (pot), kettle, reverberatory, and electric induction furnaces. The melting operation is essentially the same in all these units. The zinc is melted and heated to its pouring temperature, between 800 and 1100°F, by addition of a fossil fuel. Before the zinc is poured, fluxing material may be added to separate the dross that accumulated during the melting operation. Dross is formed by the impurities charged with the metal and by oxidation during the melting and heating cycles. The dross is skimmed from the surface of the metal, and the metal is poured into molds. Figure 3-134 presents a simplified flow diagram of the secondary zinc melting process.

The core making and sand handling systems are integral parts of a zinc foundry. These processes are described in Section 3.7.8.

Atmospheric Emissions - Particulates emitted in zinc smelting operations consist primarily of zinc oxide fumes. The emission rate depends on the cleanliness and quality of the scrap and the type of furnace. With clean zinc scrap as feed, the melting produces relatively low emissions; with dirty scrap, the emissions are approximately 25 pounds per ton of metal produced.

The type of flux can also affect the emission rate. Although many fluxes now in use do not fume, a fuming flux may be required for processing of certain batches. For example, when an ammonium chloride flux is heated to the temperature of the molten zinc, it decomposes into ammonia and hydrogen chloride; these subsequently recombine to form a submicron fume of ammonium chloride.

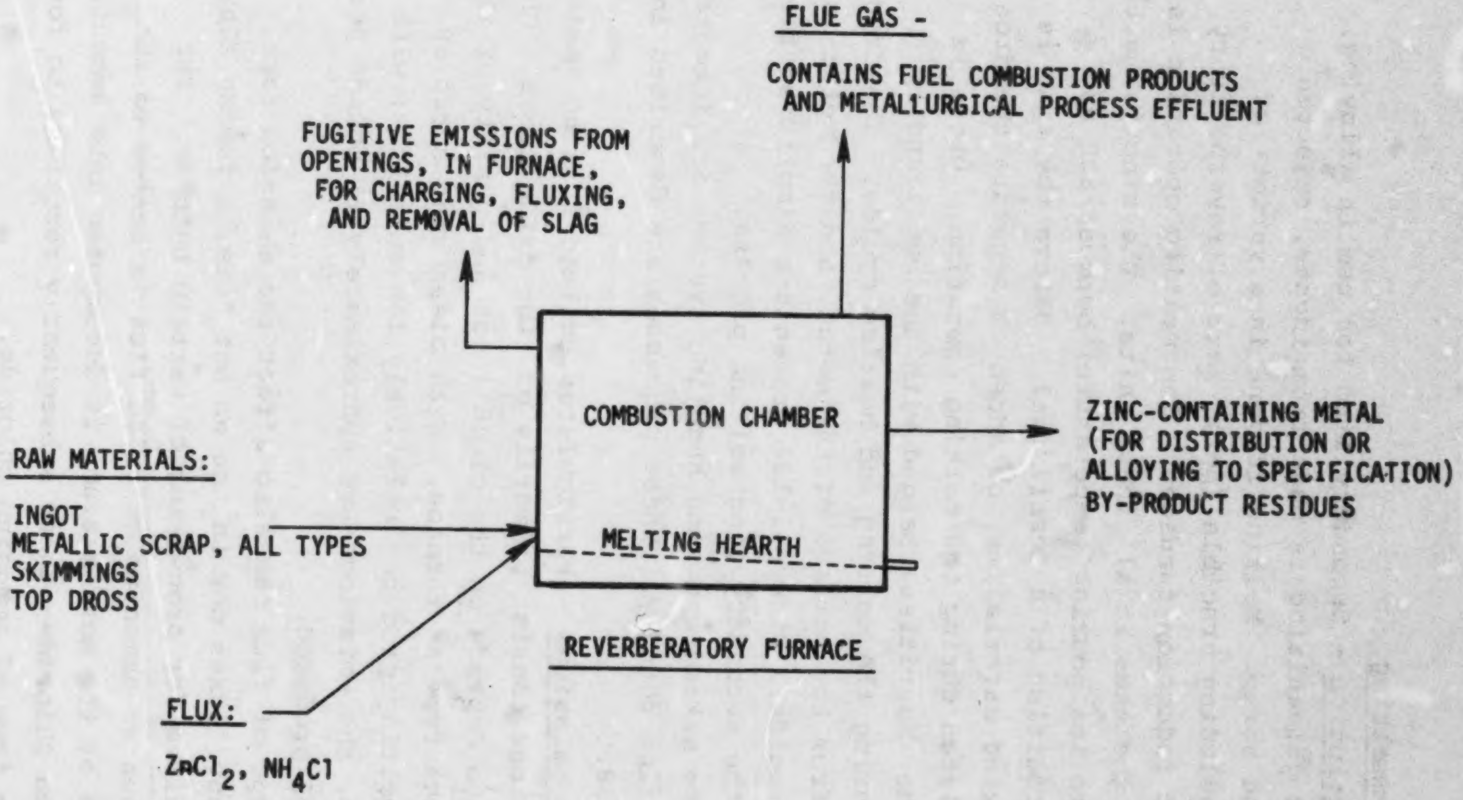

FLUE GAS -
CONTAINS FUEL COMBUSTION PRODUCTS AND METALLURGICAL PROCESS EFFLUENT
FUGITIVE EMISSIONS FROM OPENINGS, IN FURNACE, FOR CHARGING, FLUXING, AND REMOVAL OF SLAG
COMBUSTION CHAMBER
MELTING HEARTH
REVERBERATORY FURNACE
ZINC-CONTAINING METAL (FOR DISTRIBUTION OR ALLOYING TO SPECIFICATION)
BY-PRODUCT RESIDUES
RAW MATERIALS:
INGOT
METALLIC SCRAP, ALL TYPES
SKIMMINGS
TOP DROSS
FLUX:
ZnCl2, NH4Cl

Figure 3-134. Melting furnace for producing secondary zinc.

Control Systems - Process changes and control devices can reduce emissions. Use of electric induction furnaces, clean scrap, and nonfuming fluxes can substantially reduce emissions.

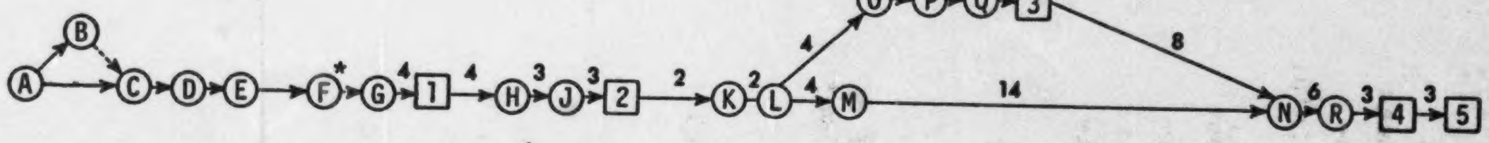
Fabric filters made of Dacron fabric are the most commonly used control devices. Gases from the furnace must be cooled to about 250°F by quenching or radiant cooling. Air-to-cloth ratios typically range between 2/1 and 3/1.

Compliance Schedules - Figure 3-135 illustrates an expeditious schedule for installation of a fabric filter on a secondary zinc furnace.

Sources of Additional Information

	Source	Type of information*
1.	Secondary Zinc Industry Emission Control Problem Definition Study. U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 201-739. May 1971. 150 p.	P, C
2.	Exhaust Gases from Combustion and Industrial Processes. Prepared by Engineering-Science, Inc. for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 204-861. October 1971. 436 p.	P
3.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, E, C

*
P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G. -

□ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	47
5	Date by which final compliance is achieved.	50

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-135. Schedule for installation of a fabric filter on a zinc smelting furnace.

3.7.7 Magnesium Smelting

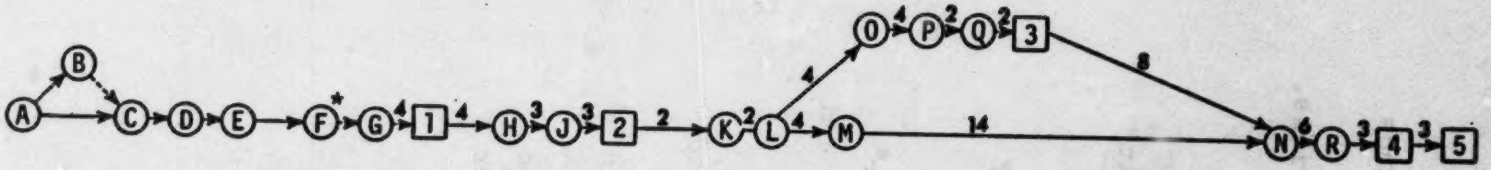
Process Description - Magnesium is smelted in steel pot furnaces with capacities ranging between 500 and 5000 pounds per batch. The raw material usually consists of scrap metal, magnesium shavings and turnings, and similar materials. The heat source is either natural gas, oil, or electric induction. A flux covers the surface of the molten metal because magnesium will burn in air at the pouring temperatures. The molten magnesium is usually cast by pouring it into molds, which are then annealed in ovens in an inert atmosphere.

Atmospheric Emissions - Particulates are the emissions of primary concern. During the first few seconds after the charging of the furnace, particulate may be emitted as a result of incomplete combustion of oils and other organic materials adhering to the scrap. Submicron metal oxides and chlorides can be emitted during the melting and refining stages.

Particulate emissions from pot furnaces are estimated to be approximately 4 pounds per ton.

Control Systems - Baghouses and high-energy wet scrubbers are used for control of particulate emissions.

Compliance Schedules - Figures 3-136 and 3-137 illustrate expeditious schedules for installation of a fabric filter and a high-energy wet scrubber, respectively.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

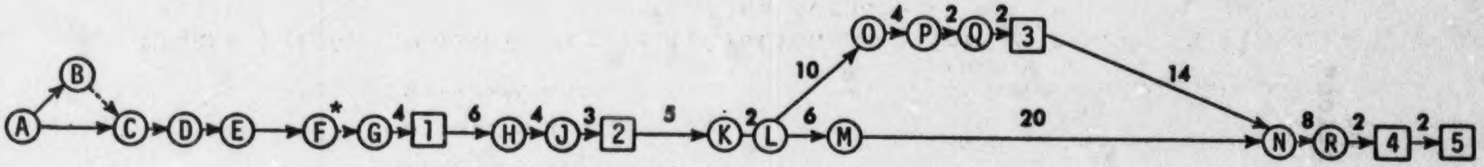
→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	47
5	Date by which final compliance is achieved.	50

Activity designation	Activity description
A-B	Conduct source tests
A-C	Perform preliminary investigation
C-D	Evaluate control alternatives
D-E	Commit funds for total program
E-F	Prepare control plan and compliance schedule for agency
F-G	Agency reviews and approves plans
G-1	Finalize plans and specifications
1-H	Procure control device bids
H-J	Evaluate control device bids
J-2	Award control device contract
2-K	Prepare assembly drawings

Activity designation	Activity description
K-L	Review and approve assembly drawings
L-M	Prepare fabrication drawings
M-N	Fabricate control device
L-O	Prepare engineering drawings
O-P	Procure construction bids
P-Q	Evaluate construction bids
Q-3	Award construction contract
3-N	Initiate on-site construction
N-R	Install control device
R-4	Complete construction and system tie-in
4-5	Perform startup, shakedown, and emission testing

Figure 3-136. Schedule for installation of a fabric filter on a magnesium smelting furnace.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	17
3	Date of initiation of on-site construction or installation of emission control equipment.	42
4	Date by which on-site construction or installation of emission control equipment is completed.	66
5	Date by which final compliance is achieved.	68

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-137. Schedule for installation of a wet scrubber system on a magnesium smelting furnace.

Sources of Additional Information

	Source	Type of information*
1.	Exhaust Gases from Combustion and Industrial Processes. Prepared by Engineering-Science, Inc. for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 204-861. October 1971. 436 p.	P, C

*P = Process description
E = Emission rates
C = Control devices

3.7.8 Core Making, Casting Shakeout, and Sand Handling

Process Description - Core making, casting shakeout, and sand handling operations are shown schematically in Figure 3-138. Cores are used in the molds to form the interior of hollow castings. The cores are prepared with binders, which usually require baking to develop the strength required to resist erosion and deformation when the mold is filled with molten metal. Several types of core ovens are in use, including shelf ovens, drawer ovens, portable-rack ovens, car ovens, and conveyor ovens. Each type is suitable for specific applications that depend on such factors as maximum size and quantity of the cores. Sand cores that are not cured in an oven before use are called green sand cores.

A heavy-duty vibrating screen is commonly used for shakeout to separate the hot casting from the sand. The sand flows through the screen and is transported to the sand conditioning system while the casting remains behind. Some foundries manually separate the casting from the sand.

Molding sand is reused continuously. The simplest sand handling system consists of a screen for removing oversize particles and a mixer in which clay and water are added to the sand to prepare it for remolding. Other equipment may be used for cooling sand, crushing oversize sand, removing fines, removing core binders, and conveying.

Atmospheric Emissions - Emissions from core making, casting shakeout, and sand handling are usually much less significant than those of other foundry operations. Emissions from the core baking oven consist primarily of condensed and gaseous hydrocarbons from the combustibles in the sand and binding materials. Rates are highly variable, depending on binder composition and baking procedures. Odors may be a problem. Emissions from the casting shakeout and sand

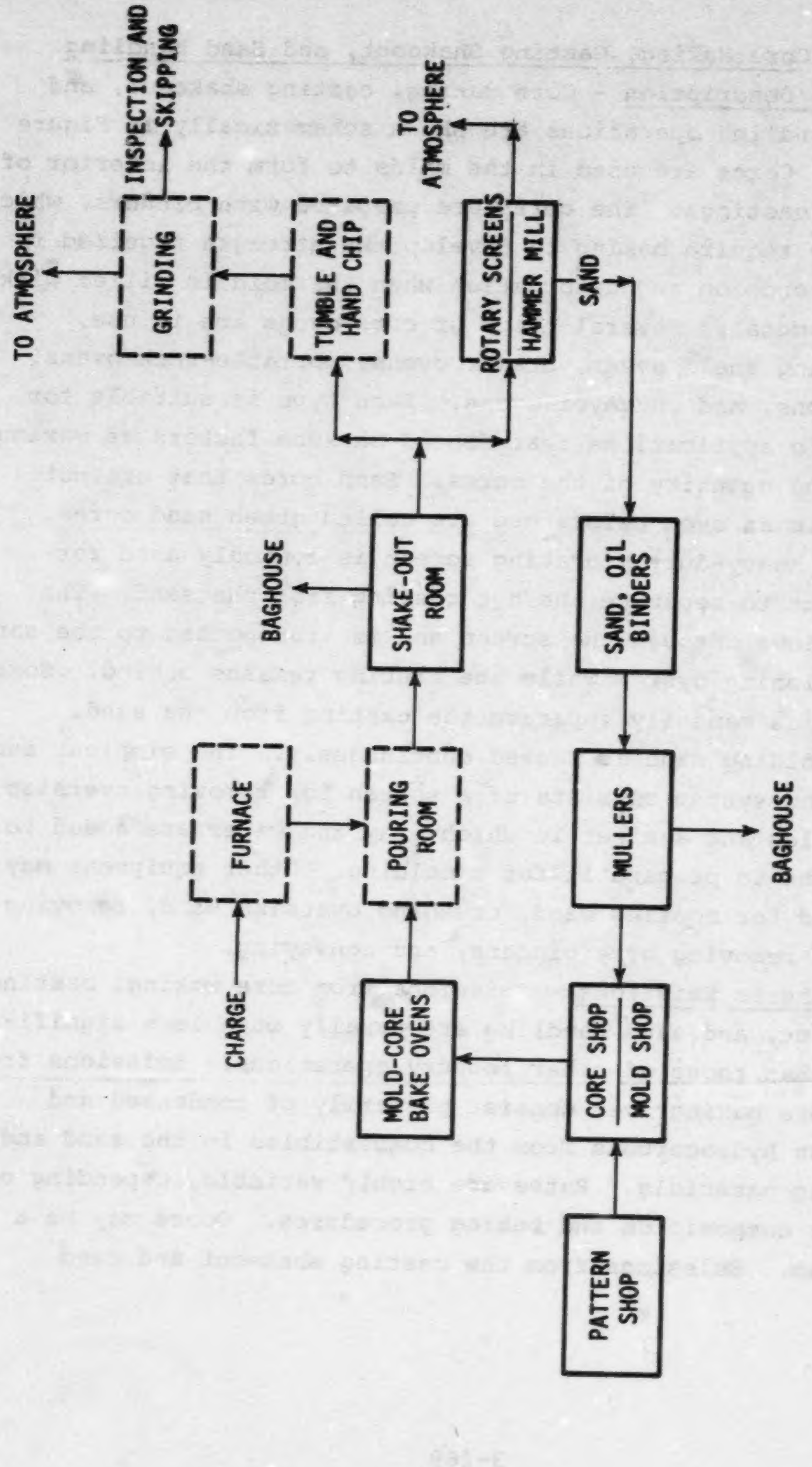
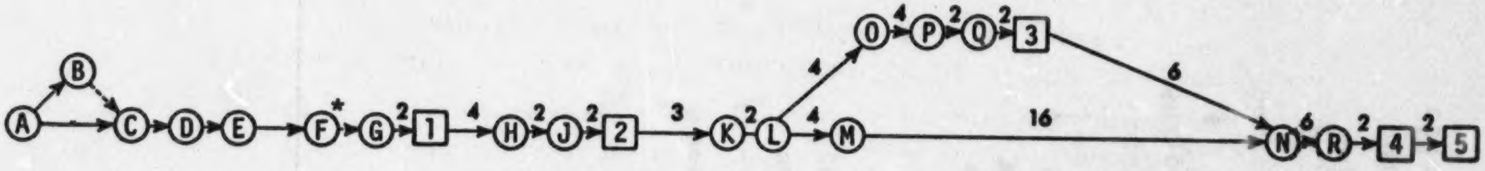

PATTERN SHOP
CORE SHOP
MOLD SHOP
MOLD-CORE BAKE OVENS
CHARGE
FURNACE
POURING ROOM
SHAKE-OUT ROOM
BAGHOUSE
TUMBLE AND HAND CHIP
GRINDING
TO ATMOSPHERE
INSPECTION AND SKIPPING
ROTARY SCREENS
HAMMER MILL
TO ATMOSPHERE
SAND
SAND, OIL BINDERS
MULLERS
BAGHOUSE

Figure 3-138. Core making, casting shakeout, and sand handling.

handling systems consist mainly of sand. Use of green cores generates some hydrocarbons as the hot casting contacts the moist cooler molding sand originally located away from the mold cavity.

Control Systems - Emissions from core ovens can be controlled by afterburners, although most ovens are not controlled. Particulate emissions from casting shakeout and sand handling systems can be controlled by low-energy scrubbers or fabric filters. Fabric filters should be used only when sand is dry because of potential plugging problems.

Compliance Schedules - Figures 3-139 through 3-141 illustrate expeditious schedules for installation of an afterburner on core ovens and a baghouse and scrubber, respectively, on the casting shakeout and sand handling operations. The major time increments for the afterburner and fabric filter installation are control device fabrication and on-site construction, estimated at 10 weeks each. Total installation times are 52 and 53 weeks for the afterburner and fabric filter, respectively. Fabrication of the low-energy scrubber is estimated to require 20 weeks of a total of 49 weeks for installation.



* Refer to Chapter 2 for time increments A to G.

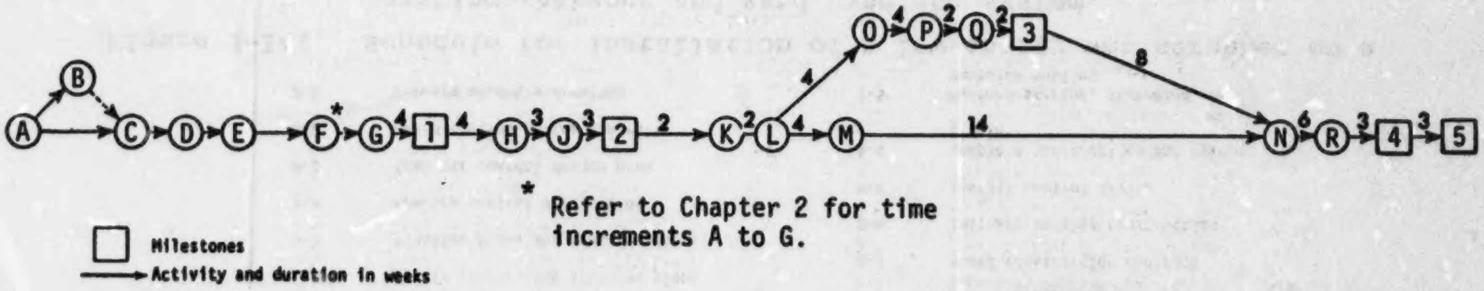
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	27
4	Date by which on-site construction or installation of emission control equipment is completed.	43
5	Date by which final compliance is achieved.	45

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-139. Schedule for installation of an afterburner on a core baking oven.

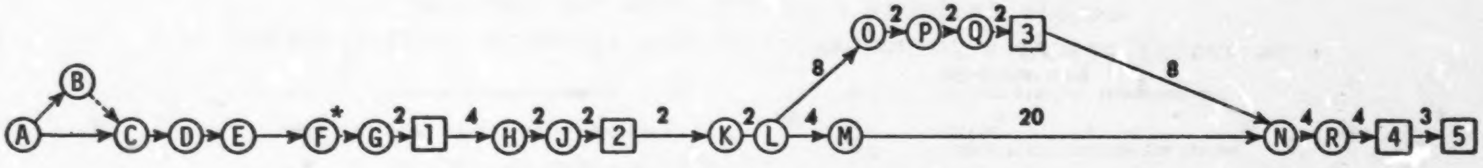


* Refer to Chapter 2 for time increments A to G.

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	47
5	Date by which final compliance is achieved.	50

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-140: Schedule for installation of a fabric filter on a casting shakeout and sand handling system.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	28
4	Date by which on-site construction or installation of emission control equipment is completed.	46
5	Date by which final compliance is achieved.	49

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-141. Schedule for installation of a low-energy wet scrubber on a casting shakeout and sand handling system.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, E, C
2.	Systems Analysis of Emissions and Emissions Control in the Iron Foundry Industry. Prepared by A.T. Kearney and Company, Inc. for U.S. Environmental Protection Agency. NTIS No. PB 198-348. February 1971. 368 p.	P, E, C
3.	Air Pollution Aspects of the Iron Foundry Industry. Prepared by A.T. Kearney and Company, Inc. for U.S. Environmental Protection Agency. NTIS No. 204 712. February 1971. 260 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices

3.7.9 Metallurgical Chlorination

Process Description - Chlorination is the bubbling of chlorine gas through molten aluminum to reduce the magnesium content of the molten metal or to remove dissolved gases. Typically, chlorine gas is injected beneath the surface of the molten aluminum bath through one or more lances. The chlorine reacts with magnesium and/or dissolved gases to form chlorides, which rise to the surface where they are removed by skimming.

Atmospheric Emissions - The rapid addition of chlorine during demagging causes emissions of aluminum chloride, chlorine gas, and magnesium chloride. The aluminum chloride readily absorbs moisture from the air, with which it reacts to form hydrogen chloride.

An uncontrolled chlorination station emits about 1000 pounds of particulates per ton of chlorine consumed (about 12.5 pounds per ton of metal produced).[2] The amounts of specific pollutants emitted depend mainly upon the quantity of chlorine, the magnesium content of the aluminum, and the temperature of the molten metal. An excess of chlorine increases emissions of aluminum chloride, hydrogen chloride, and chlorine.

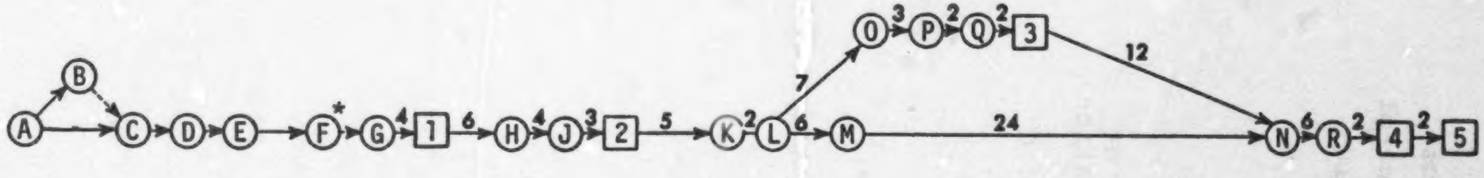
Control Systems - For the chlorination station, a high-energy wet scrubber followed by a gas absorption tower should provide effective control of the submicron particulates. Pressure drops of 50 to 60 inches water gauge may be required to control particulate emissions effectively. Test data have shown that use of a packed column scrubber with a 10 percent caustic solution can remove 99 percent of the hydrogen chloride, 90 to 95 percent of the chlorine, and 80 to 90 percent of the particulate.[1] In addition, careful control of the chlorination rate minimizes emissions.

Compliance Schedules - Figure 3-142 shows an expeditious schedule for installation of a scrubbing system for control of particulate, hydrogen chloride, and chlorine. Total installation time is 64 weeks, including 24 weeks for control device fabrication.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. pp. 283-292.	P, E, C
2.	Compilation of Air Pollutant Emission Factors. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. pp. 7.8-1 and 7.8-2.	E
3.	Feasibility and Costs of Particulate Control Systems for U.S. Reduction Company, Toledo, Ohio. Prepared by PEDCo-Environmental Specialists, Inc. for Ohio Environmental Protection Agency, Columbus, Ohio. November 1974. 46 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	17
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	62
5	Date by which final compliance is achieved.	64

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-142. Schedule for installation of a wet scrubber system for control of emissions from metallurgical chlorination.

3.8 MINERAL INDUSTRIES

3.8.1 Portland Cement

Process Description - Portland cement is manufactured by dry and wet processes, both of which include four major steps: quarrying and crushing, grinding and blending, clinker production through calcination, and finished grinding and packaging.

In the wet process, the wet, ground material is pumped in slurry form to large mixing tanks, from which it is subsequently pumped to the kilns. In the dry process, the dry, ground material is conveyed to storage bins and then fed to the kilns. In the first section of the kiln, the ground material is heated and dried. As it progresses through the kiln it is calcined and heated until it fuses, forming clinker. The clinker is discharged from the kiln and cooled in a clinker cooler. Gypsum is added, and the mixture is ground to produce finished cement.

A simplified flow diagram of cement plant operation is shown in Figure 3-143.

Atmospheric Emissions - More than a dozen process steps in a typical cement plant require effective emission control. These processes encompass widely varying conditions of temperature, dust load, air volumes, and particle sizes; all require high-efficiency collection systems.

The major source of particulate emission from both dry and wet processes is the calcining kiln. Dust is generated by the tumbling action within the kiln as well as by volatilization of components during calcination. Secondary sources of particulate emission are the clinker cooler and the grinders.

Particulate emissions from the calcining kiln are estimated at 228 pounds of particulate per ton of cement pro-

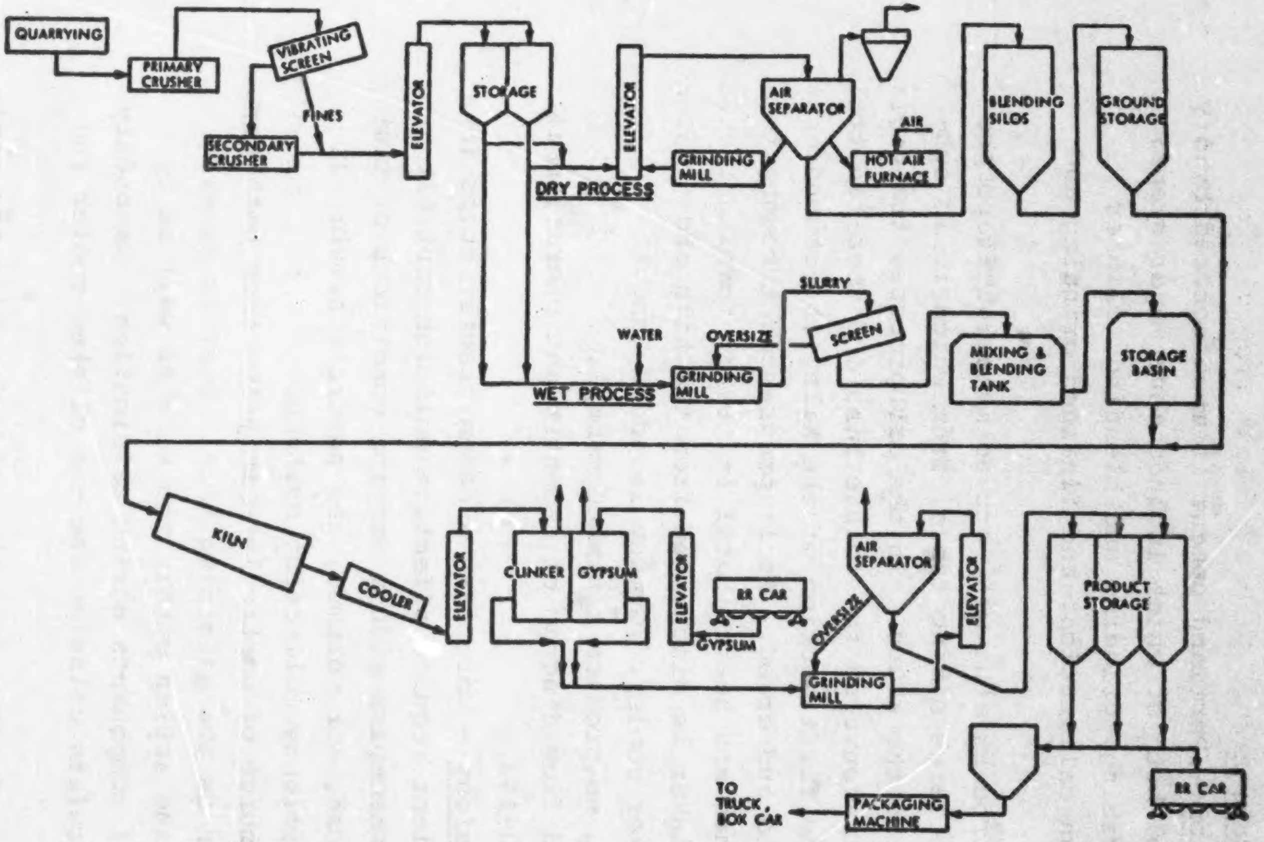

QUARRYING
PRIMARY CRUSHER
VIBRATING SCREEN
FINES
SECONDARY CRUSHER
ELEVATOR
STORAGE
DRY PROCESS
ELEVATOR
GRINDING MILL
AIR SEPARATOR
AIR
HOT AIR FURNACE
BLENDING SILOS
GROUND STORAGE
WATER
OVERSIZE
WET PROCESS
GRINDING MILL
SLURRY
SCREEN
MIXING & BLENDING TANK
STORAGE BASIN
KILN
COOLER
ELEVATOR
CLINKER
GYPSUM
ELEVATOR
RR CAR
GYPSUM
AIR SEPARATOR
OVERSIZE
GRINDING MILL
ELEVATOR
PRODUCT STORAGE
RR CAR
PACKAGING MACHINE
TO TRUCK, BOX CAR

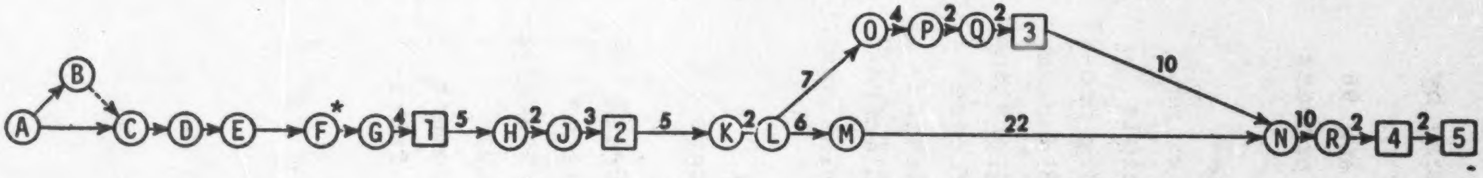
Figure 3-143. Cement manufacture.

duced by the wet process and 245 pounds per ton produced by the dry process.[2] Particulate emissions from clinker coolers, dryers, and grinders are estimated to be 32 and 96 pounds per ton of cement produced by the wet and dry process respectively.[2]

Control Systems - Fabric filters and electrostatic precipitators are used to control emissions from cement kilns. These devices are often installed in series with multiple cyclones. Fabric filters are more commonly used on dry process systems because of their higher collection efficiencies and relative insensitivity to variations in process operating conditions; they are also used occasionally on wet process systems. Fabric filters are also used to control emissions from various transferring and handling operations. Electrostatic precipitators are used primarily to control emissions from kilns on wet process plants.

Emissions from the dryers, grinders, and clinker coolers can be controlled by fabric filters or scrubbers if required.

Compliance Schedules - Figures 3-144 and 3-145 illustrate expeditious schedules for installation of a fabric filter and an electrostatic precipitator on a cement kiln. Installation of a fabric filter requires 63 weeks, including 22 weeks for fabrication. Installation of an ESP on a cement kiln requires about 75 weeks, including 28 weeks for fabrication.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

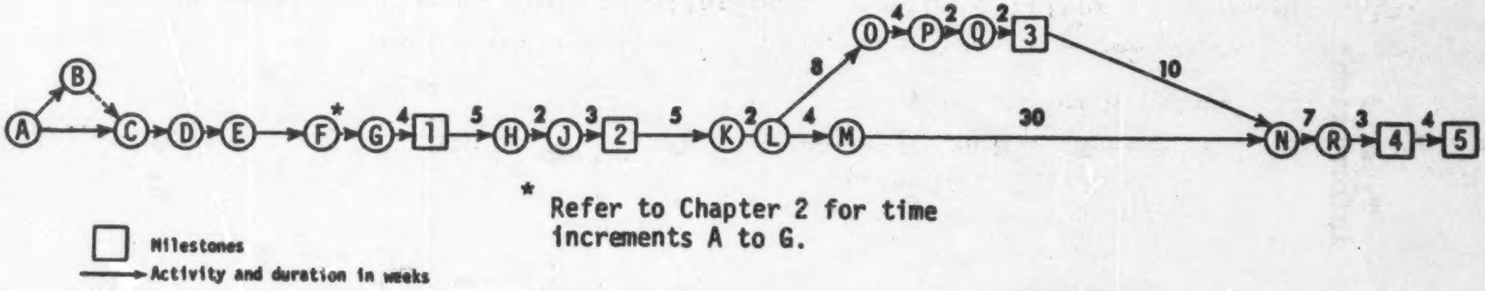
→ Activity and duration in weeks

MILESTONES

		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	36
4	Date by which on-site construction or installation of emission control equipment is completed.	61
5	Date by which final compliance is achieved.	63

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-144. Schedule for installation of a fabric filter on a cement kiln.



* Refer to Chapter 2 for time increments A to G.

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	37
4	Date by which on-site construction or installation of emission control equipment is completed.	65
5	Date by which final compliance is achieved.	69

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-145. Schedule for installation of an electrostatic precipitator on a cement kiln.

Sources of Additional Information

	Source	Type of information*
1.	Atmospheric Emissions from the Manufacture of Portland Cement. National Center for Air Pollution Control, Cincinnati, Ohio. Publication No. AP-17. 1967. 53 p.	P
2.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. February 1976. pp. 8.6-1 through 8.6-4.	E
3.	Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Prepared by Midwest Research Institute for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 203 522. May 1971. 613 p.	P, E, C
4.	A Manual of Electrostatic Precipitator Technology. Part II - Application Areas. Prepared by Southern Research Institute for the U.S. Environmental Protection Agency. NTIS No. PB 196-381. August 1970. 584 p.	C
5.	Background Information for Proposed New-Source Performance Standards: Steam Generators, Incinerators, Portland Cement Plants, Nitric Acid Plants and Sulfuric Acid Plants. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. PB 202-459. August 1971. 61 p.	C
6.	Air Pollution Aspects of Emission Sources: Cement Manufacturing. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. PB 200-080. May 1971. 51 p.	E, C

***P = Process description**
E = Emission rates
C = Control devices

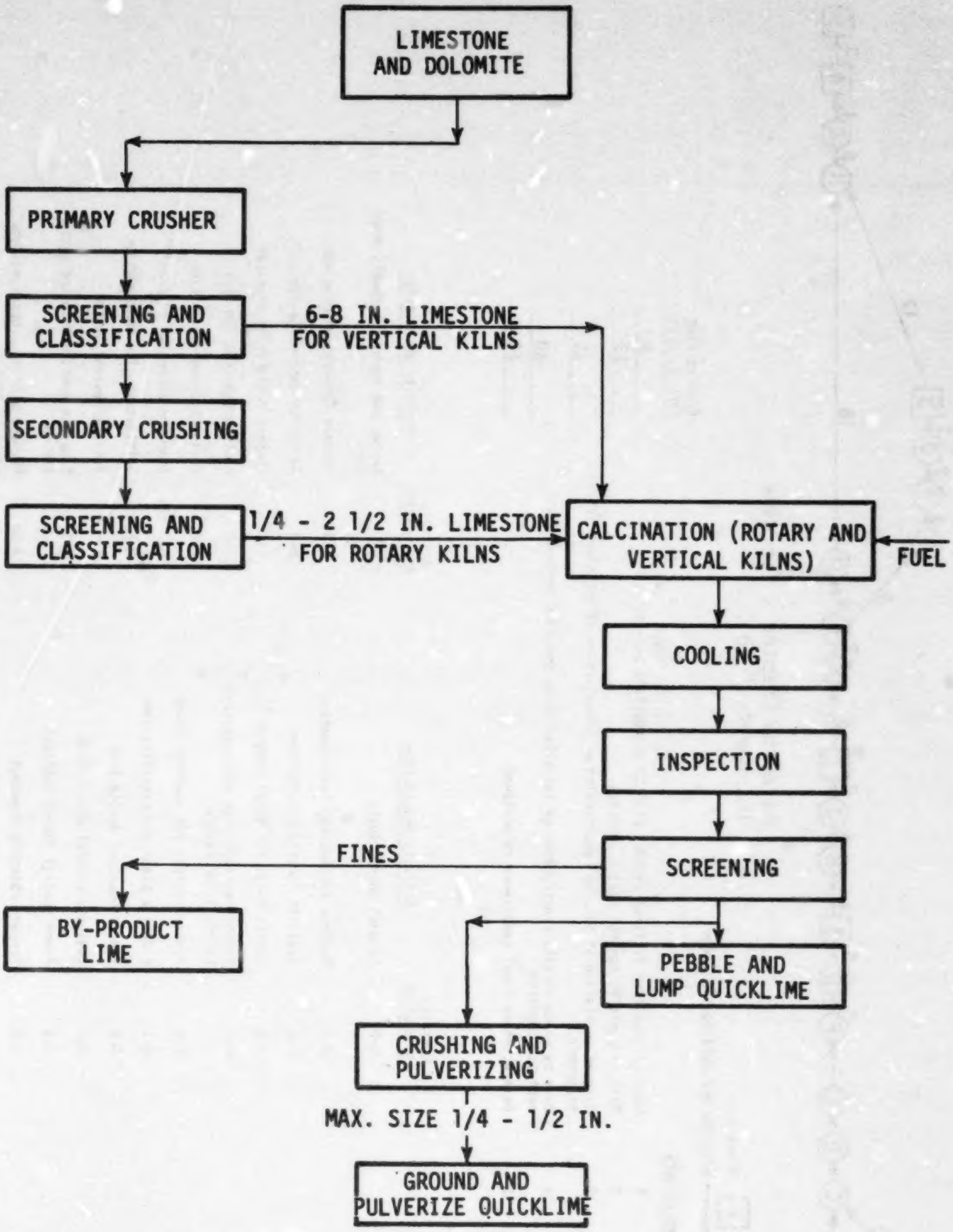
3.8.2 Lime

Process Description - The principal raw materials for lime manufacture are calcium carbonate (limestone) or calcium-magnesium carbonate (dolomite or dolomitic limestone). The limestone or dolomite is heated in a vertical or horizontal (rotary) kiln to decompose the carbonate. Heating releases CO_2 and leaves calcium and magnesium oxide as products. The heating process also drives off moisture and volatile organic matter. Figure 3-146 illustrates the lime manufacturing process.

Atmospheric Emissions - The major source of particulate emission is the calcining kiln. Emissions vary with type of kiln and composition of the limestone. Vertical kilns emit less than rotary kilns because larger sizes of limestone are charged, gas velocities are lower, and less attrition occurs. In rotary kilns, abrasion of limestone produces dust, which is entrained by the high-velocity combustion gases. Particulate emission from a rotary kiln, if uncontrolled, is about 200 pounds per ton of lime processed. Emissions from vertical kilns are approximately 8 pounds per ton.

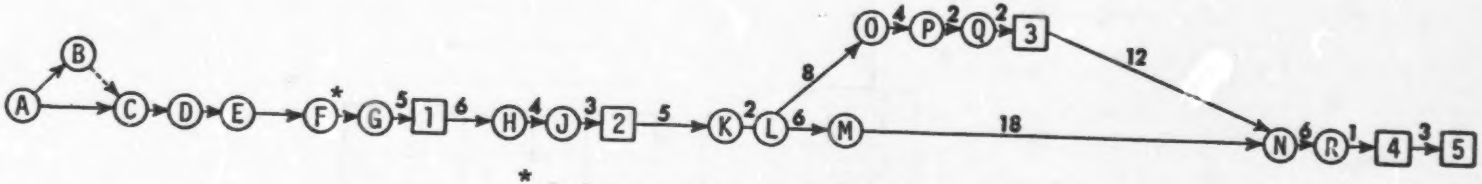
Control Systems - Most rotary kilns incorporate a settling chamber or cyclone precleaner to remove coarse particles. Wet scrubbers and fabric filters with glass or Nomex fabric are used for high-efficiency particulate collection. Electrostatic precipitators are also used, but not as frequently as fabric filters or wet scrubbers.

Compliance Schedules - Figures 3-147 and 3-148 illustrate expeditious schedules for installation of a wet scrubber and a fabric filter on lime kilns.



LIMESTONE AND DOLOMITE
PRIMARY CRUSHER
SCREENING AND CLASSIFICATION
6-8 IN. LIMESTONE FOR VERTICAL KILNS
SECONDARY CRUSHING
SCREENING AND CLASSIFICATION
1/4 - 2 1/2 IN. LIMESTONE FOR ROTARY KILNS
CALCINATION (ROTARY AND VERTICAL KILNS)
FUEL
COOLING
INSPECTION
SCREENING
FINES
BY-PRODUCT LIME
PEBBLE AND LUMP QUICKLIME
CRUSHING AND PULVERIZING
MAX. SIZE 1/4 - 1/2 IN.
GROUND AND PULVERIZE QUICKLIME

Figure 3-146. Manufacture of lime and limestone products.



* Refer to Chapter 2 for time increments A to G.

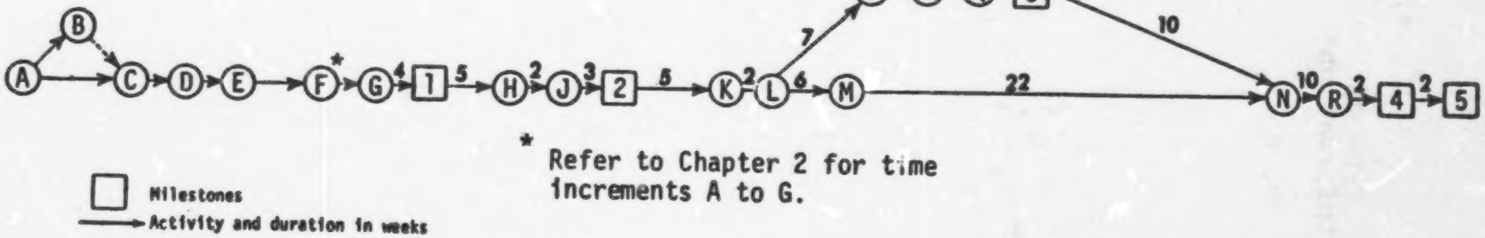
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	5
2	Date of award of control device contract.	18
3	Date of initiation of on-site construction or installation of emission control equipment.	41
4	Date by which on-site construction or installation of emission control equipment is completed.	60
5	Date by which final compliance is achieved.	63

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-147. Schedule for installation of wet scrubber on a lime kiln.



* Refer to Chapter 2 for time increments A to G.

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	36
4	Date by which on-site construction or installation of emission control equipment is completed.	61
5	Date by which final compliance is achieved.	63

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-148. Schedule for installation of fabric filter on a lime kiln.

Sources of Additional Information

	Source	Type of information*
1.	Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Prepared by Midwest Research Institute for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 203 522. May 1971. 613 p.	P, E
2.	Study of Technical and Cost Information for Gas Cleaning Equipment in the Lime and Secondary Nonferrous Metallurgical Industries. Prepared by the Industrial Gas Cleaning Institute, Inc. for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. PB 198-137. December 1970. 307 p.	C

*
P = Process description
E = Emission rates
C = Control devices

3.8.3 Phosphate Rock

Process Description   Phosphate rock processing involves beneficiating the ore to reduce impurities, drying to remove moisture, and grinding to enhance reactivity during subsequent processing steps, as in reaction with sulfuric acid to produce phosphoric acid. A simplified phosphate rock processing operation is shown in Figure 3-149.

Atmospheric Emissions - The major sources of particulate emissions are the grinding and drying operation; open storage piles can cause significant emissions of fugitive dust. Emissions from uncontrolled phosphate rock processing range from approximately 2 pounds per ton of rock from transfer and conveying systems to 40 pounds per ton from open storage piles. Drying and grinding operations emit 15 to 20 pounds per ton of rock processed.

Control Systems - Fabric filters are the most commonly used high-efficiency control devices, operating with collection efficiencies above 99 percent.

Compliance Schedules - Figure 3-150 illustrates an expeditious schedule for installation of a fabric filter on phosphate rock processing operations.

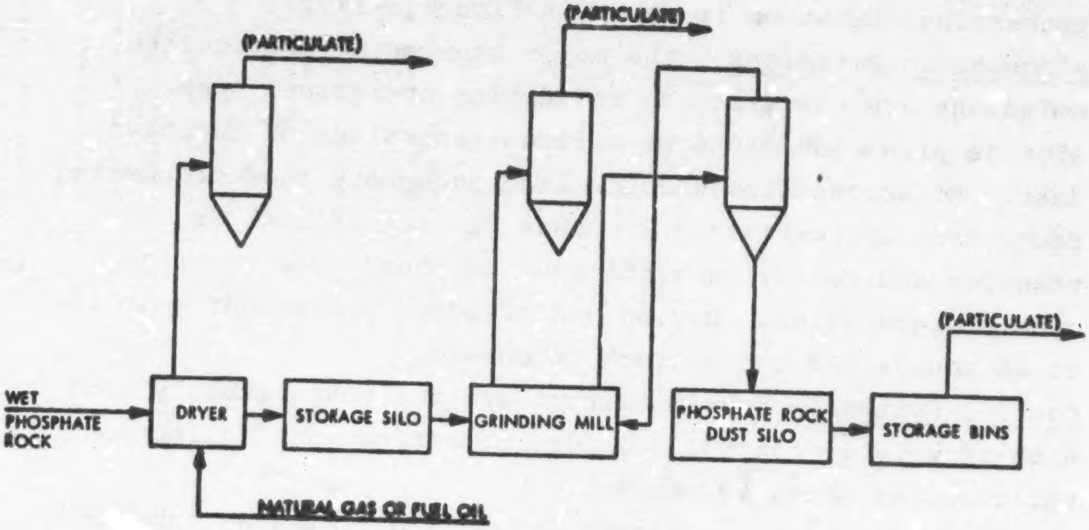
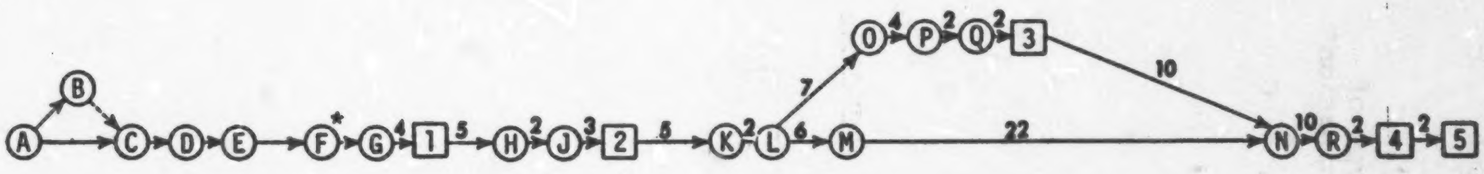

(PARTICULATE)
(PARTICULATE)
(PARTICULATE)
WET PHOSPHATE ROCK
DRYER
STORAGE SILO
GRINDING MILL
PHOSPHATE ROCK DUST SILO
STORAGE BINS
NATURAL GAS OR FUEL OIL

Figure 3-149. Phosphate rock processing.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones
——→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	39
4	Date by which on-site construction or installation of emission control equipment is completed.	65
5	Date by which final compliance is achieved.	69

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-150. Schedule for installation of fabric filter on a phosphate rock processing operation.

Sources of Additional Information

	Source	Type of information*
1.	Handbook of Emissions, Effluents, and Control Practices for Stationary Particulate Pollution Sources. NTIS No. PB 203-522.	P, E, C
2.	Kirk-Othmer, Encyclopedia of Chemical Technology 2nd Edition. Interscience Publishers. New York, New York.	P
3.	Air Pollution Control Field Operations Manual. APTD Publication No. 1164.	P

*P = Process description
E = Emission rates
C = Control devices

3.8.4 Glass

Process Description - At a typical soda-lime glass plant, the raw materials are glass sand, soda ash, limestone, cullet (broken glass), and minor ingredients. These are batch-weighed, mixed, and charged to a glass furnace, in which the dry mixture blends with molten glass. The batch is mixed for homogeneity and heat-conditioned to eliminate stones.[1] The two major types of furnace used in the glass industry are regenerative and electric.

Capacities of regenerative furnaces range from 50 to 300 tons of glass per day. These furnaces are direct-fired with oil or gas and are operated continuously. Some systems incorporate an electric induction booster system to increase furnace capacity. Electric induction is also used to melt glass on a large scale. Although melting glass by electricity is more expensive, it is more thermally efficient since the heat is supplied directly.[2]

The molten glass from the furnace is partially cooled and worked on forming machines by such methods as pressing, drawing, rolling, casting, and blowing in molds. The glass articles are immediately conveyed to gas fired or electrically heated annealing ovens, in which they are heat-treated to remove strains developed during molding.

A flow diagram of a soda-lime glass plant is shown in Figure 3-151.

Atmospheric Emissions - Particulates can be emitted during the unloading and transferring of raw materials. Emissions from the glass furnace, however, present the most serious problem. The rate of particulate emission from the furnaces varies considerably, depending upon the composition of the glass produced and on the furnace design and operating conditions. An estimated 2.0 pounds of particulate is

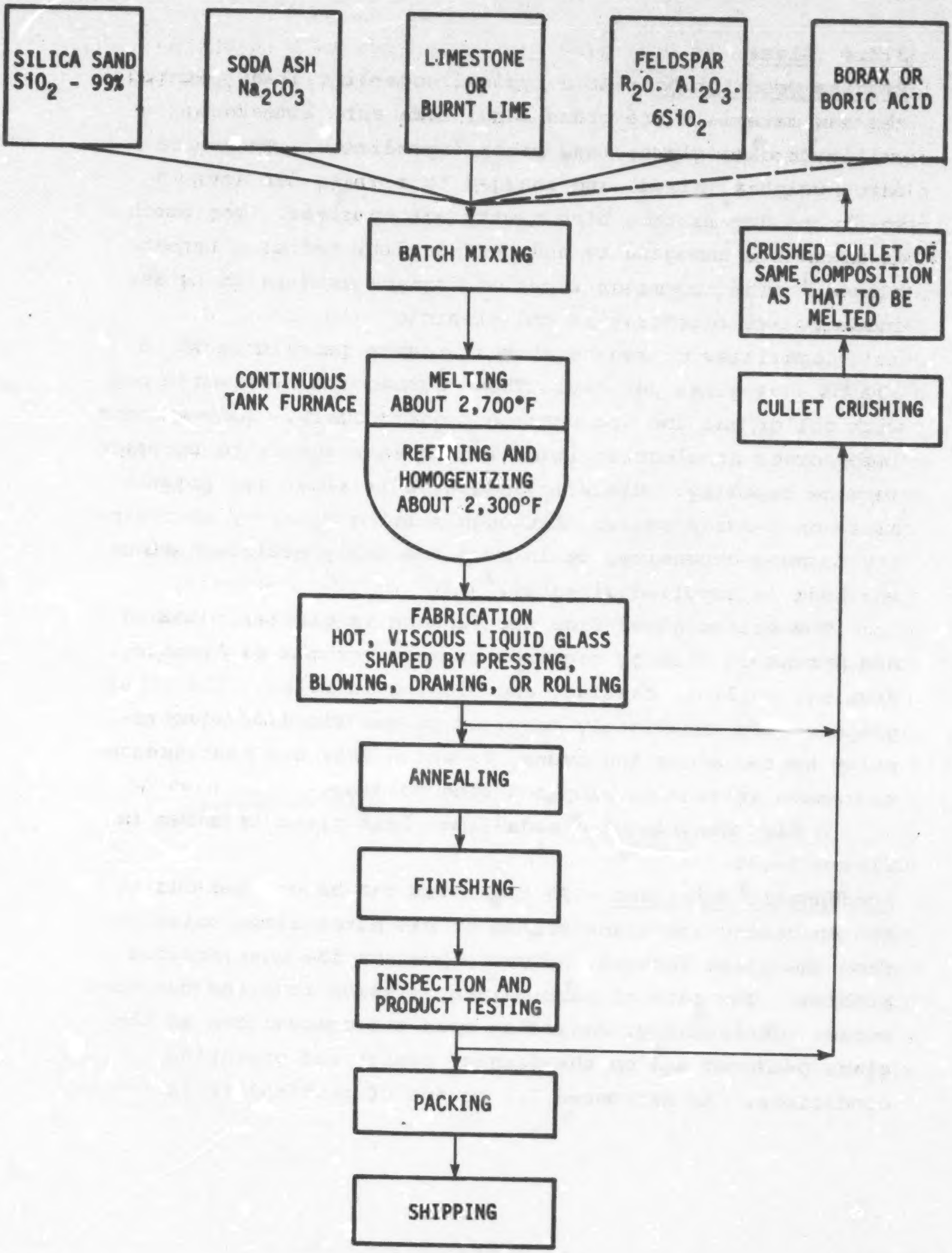

SILICA SAND SiO_2 - 99%
SODA ASH Na_2CO_3
LIMESTONE OR BURNT LIME
FELDSPAR $R_2O \cdot Al_2O_3 \cdot 6SiO_2$
BORAX OR BORIC ACID
BATCH MIXING
CRUSHED CULLET OF SAME COMPOSITION AS THAT TO BE MELTED
CONTINUOUS TANK FURNACE
MELTING ABOUT 2,700°F
REFINING AND HOMOGENIZING ABOUT 2,300°F
CULLET CRUSHING
FABRICATION HOT, VISCOUS LIQUID GLASS SHAPED BY PRESSING, BLOWING, DRAWING, OR ROLLING
ANNEALING
FINISHING
INSPECTION AND PRODUCT TESTING
PACKING
SHIPPING

Figure 3-151. Soda-lime glass manufacture.

emitted per ton of soda-lime glass produced in a regenerative furnace.[3] No data are available on electrically heated furnaces, but particulate emissions should be significantly less. Emissions from production of container glass and plate glass, both soda-lime glasses, generally are lower than those from production of specialty glasses. Particulate emissions result both from entrainment of batch constituents in the combustion air and from vaporization of certain volatile components in the melt. The volatile constituents subsequently condense to form particulates. Sulfates, fluorides, and borates are common batch constituents causing volatilization. The great variety of compounds used to produce the hundreds of specialty glasses can create substantial emissions problems, including the potential for emitting hazardous air pollutants.

Emissions from container-glass forming operations are due to the volatilization of the mold coating compounds, which create a constant haze in the vicinity of the glass forming machine. Emissions from annealing ovens are negligible.

Control Systems - Fugitive dust emissions from unloading of raw materials can be effectively controlled by use of choked feeding and proper enclosures. Vent filters can be used on bin filling and conveying operations. Fabric filters can be used on mixers and weigh hoppers.

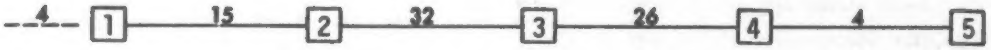
Only a few continuously operating control devices are used on glass furnaces. The most effective systems currently used are fabric filters and wet scrubbers. High-energy venturi scrubbers are capable of collection efficiencies above 95 percent but require a pressure drop of approximately 50 inches of water.

Particulate collection efficiencies of baghouses are higher than 99 percent, but bag failures due to acid gases and high temperatures are a problem. On furnaces processing tableware and opal glass, fabric filters have proved effective.

Whenever possible, many soda-lime glass plants are changing batch compositions to reduce emissions and comply with emission regulations. Emissions of volatized materials are reduced by elimination or reduction of various refining agents such as sulfates. Also, the fluoride content of the batch in many plants has been reduced or eliminated to minimize fluoride emissions.

Electric furnaces offer a much lower emissions potential than gas- or oil-fired furnaces. Several plants have replaced older furnaces with electric furnaces to meet emission regulations. At many plants, however, the use of an electric furnace in lieu of installing control devices is not economically feasible or is precluded by the composition of the feed, which dictates whether the change to an electric furnace would reduce emissions enough to achieve compliance.

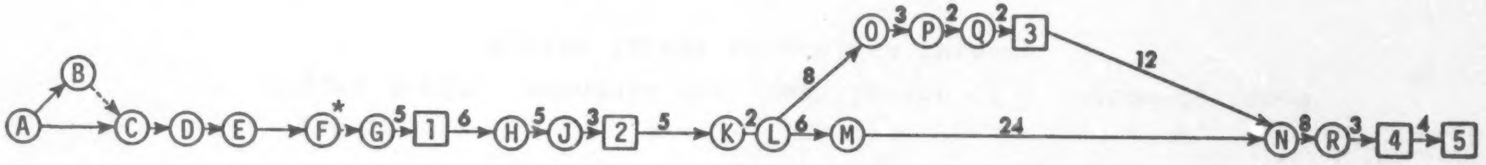
Compliance Schedules - Figures 3-152 and 3-153 illustrate expeditious schedules for installation of a fabric filter and a high-energy venturi scrubber, respectively, on a glass furnace.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	51
4	Date by which on-site construction or installation of emission control equipment is completed.	77
5	Date by which final compliance is achieved.	81

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-152. Schedule for installation of a custom-designed fabric filter on a glass furnace.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	5
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	41
4	Date by which on-site construction or installation of emission control equipment is completed.	67
5	Date by which final compliance is achieved.	71

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-153. Schedule for installation of high-energy venturi scrubber on a glass furnace.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. pp. 765-782.	P, E, C
2.	Stockham, John D. The Composition of Glass Furnace Emissions. Journal of the Air Pollution Control Association. 21(11):713-715, 1971.	E
3.	Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition. Volume 10. Interscience Publishers, New York, 1969. pp. 533-604.	P
4.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. February 1976. p. C-16.	E

*P = Process description
E = Emission rates
C = Control devices

3.8.5 Fiber Glass

Process Description - The manufacture of fiber glass consists of melting various raw materials to form molten glass, drawing the glass into fibers, and coating the fibers with an organic material (the binder). When the fiber glass is to be used in textile products, the glass is often formed into marbles before it is drawn into fiber filaments. In the manufacture of wool products, the molten glass is normally fed directly into the forming line.

The processes, emissions, and control methods for the raw material handling operations and the glass melting furnace are similar to those described in Section 3.8.4 for production of glass products. Fiber glass, however, is mainly borosilicate glass, whereas 90 percent of other glass manufacturing is from soda lime.

Glass wool is formed by feeding glass through platinum bushings to form fine fibers. The fibers are sprayed with binders, cured at 400 to 500°F, air-cooled, and cut to proper size. Figure 3-154 illustrates the overall fiber glass production processes.

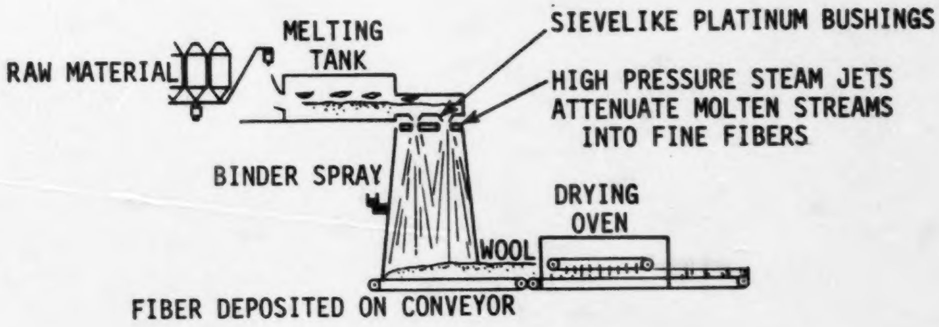

MELTING TANK
SIEVELIKE PLATINUM BUSHINGS
RAW MATERIAL
HIGH PRESSURE STEAM JETS ATTENUATE MOLTEN STREAMS INTO FINE FIBERS
BINDER SPRAY
DRYING OVEN
WOOL
FIBER DEPOSITED ON CONVEYOR

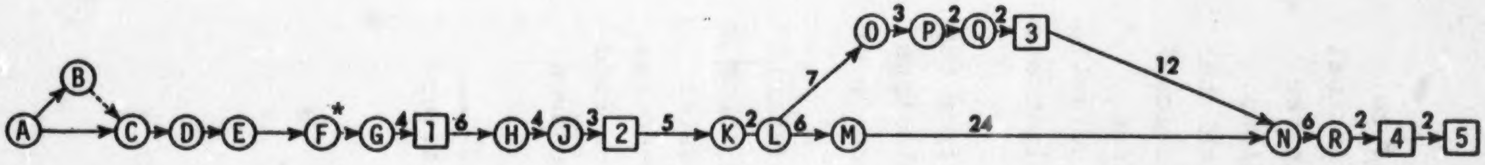
Figure 3-154. Fiber glass production.

Atmospheric Emissions - Furnace emissions are similar to those discussed for glass manufacturing, with the principal difference that spraying resins on the glass fiber in the forming operation creates substantial volatile emissions. Components in the resin are driven off by contact with the hot fibers and subsequently condense to form fine particulates. The emissions are increased by use of very fine binder sprays and binders with a high percentage of volatile components. Particulate emissions from the forming line are estimated to be 50 pounds per ton processed.[3]

The curing ovens also emit volatile components from the binder; when these condense upon cooling, visible emissions occur. Curing oven emissions are estimated at 7.0 pounds of particulate per ton of fiber glass wool processed.[3]

Control Systems - The High-Energy Air Filter device (HEAF) is a widely used emission control method for forming lines and curing ovens. Pressure drops of over 30 inches water gauge are required for satisfactory operation. High-energy wet scrubbers, wet ESP's, and afterburners can also be used to control emissions from the forming line and curing oven.

Compliance Schedules - Figures 3-155 through 3-158 illustrate expeditious schedules for installation of a high-energy wet scrubber, a HEAF unit, a wet ESP, and an afterburner on forming line and curing oven sources.



* Refer to Chapter 2 for time increments A to G.

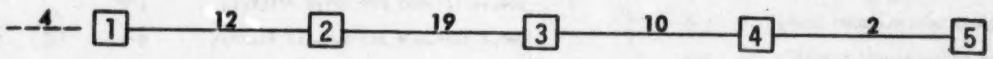
☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	40
4	Date by which on-site construction or installation of emission control equipment is completed.	64
5	Date by which final compliance is achieved.	66

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

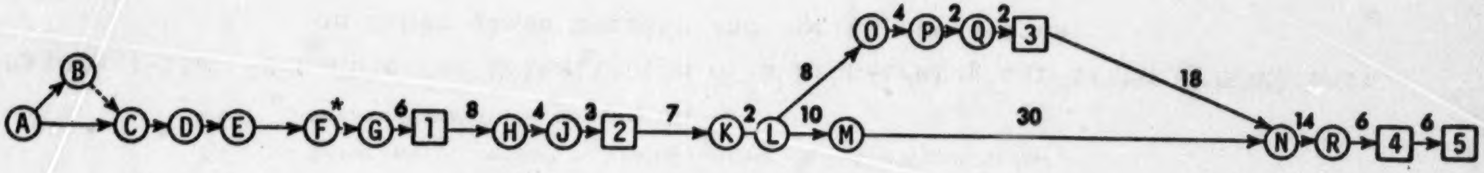
Figure 3-155. Schedule for installation of a high-energy wet scrubber on fiber glass forming and curing operations.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	35
4	Date by which on-site construction or installation of emission control equipment is completed.	45
5	Date by which final compliance is achieved.	47

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-156. Schedule for installation of a high-energy air filter (HEAF) unit on fiber glass forming and curing operations.



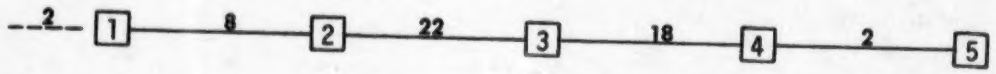
* Refer to Chapter 2 for time increments A to G.

☐ Milestones
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	6
2	Date of award of control device contract.	21
3	Date of initiation of on-site construction or installation of emission control equipment.	46
4	Date by which on-site construction or installation of emission control equipment is completed.	90
5	Date by which final compliance is achieved.	96

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-157. Schedule for installation of a wet electrostatic precipitator on fiber glass forming and curing operations.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	32
4	Date by which on-site construction or installation of emission control equipment is completed.	50
5	Date by which final compliance is achieved.	52

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-158. Schedule for installation of an afterburner on fiber glass forming and curing operations.

Sources of Additional Information

Source	Type of information*
1. Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition. Volume 10. Interscience Publishers, New York, 1969. pp. 533-604.	P
2. Danielson, J.A., editor. Air Pollution Engineering Manual, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. pp. 765-782.	P, E, C
3. Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976. p. C-16.	E

*P = Process description
E = Emission rates
C = Control devices

3.8.6 Asphalt Batching

Process Description - Asphalt batch processing consists of drying and heating various aggregates, screening, proportioning, weighing, and mixing the hot dry aggregate with molten asphalt. Both continuous and batch mix plants are in operation. The processes are similar except for the final weighing and mixing steps, which are done either continuously or batchwise. Capacities of asphalt batch plants range from 50 to 300 tons per hour.

As shown in Figure 3-159, aggregate consisting of crushed stone, slag, and gravel or sand is sized and loaded in a storage hopper. From the hopper it flows into the elevated end of a rotary dryer. A gas or oil burner supplies heat directly at the lower or discharge end of the dryer. After drying, the hot aggregate is screened and mixed with hot asphalt.

Atmospheric Emissions - Conveyor belt and bucket elevator transfer points, bin loading, and screening operations can be sources of fugitive dust emission. The combustion gas stream from the rotary dryer, however, is the primary source of particulate emissions. This stream usually passes through a cyclone precleaner to remove some particulate, but emissions still amount to about 5 pounds per ton of product. The particulate emission rate increases as the particle size of the aggregate decreases.

Control System - Covering belt conveyors, elevators, screens, bins and other handling operations, and venting the displaced air through a fabric filter system will effectively control emissions from these sources.

A cyclone precleaner followed by a fabric filter or high-energy wet scrubber can be used to reduce particulate emissions from the rotary dryer. Scrubber systems should

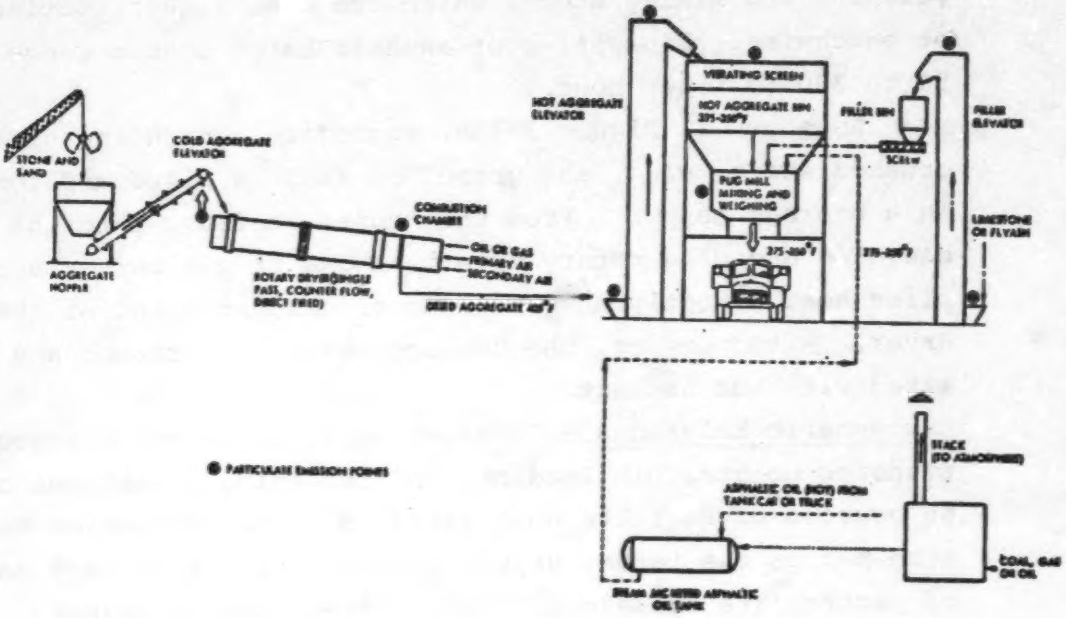

STONE AND SAND
AGGREGATE HOPPER
COLD AGGREGATE ELEVATOR
COMBUSTION CHAMBER
OIL OR GAS
PRIMARY AIR
SECONDARY AIR
ROTARY DRYER (SINGLE PASS, COUNTER FLOW, DIRECT FIRED)
DRIED AGGREGATE 400°F
HOT AGGREGATE ELEVATOR
VIBRATING SCREEN
HOT AGGREGATE BIN 275-350°F
PUG MILL MIXING AND WEIGHING
275-350°F
275-350°F
FILLER BIN
FILLER ELEVATOR
SCREW
LIMESTONE OR FLYASH
PARTICULATE EMISSION POINTS
STACK (TO ATMOSPHERE)
ASPHALTIC OIL (HOT) FROM TANK CAR OR TRUCK
STEAM AGITATED ASPHALTIC OIL TANK
COAL, GAS OR OIL

Figure 3-159. Asphalt batch process.

provide at least 10 gallons of water per 1000 standard cubic feet of exhaust gas. Pressure drops through the scrubber should be in the range of 10 to 20 inches of water. Fabric filter systems commonly use glass fiber or Nomex fabric and operate at air-to-cloth ratios of 3.5/1 to 6.5/1 (cubic foot per minute per square foot).

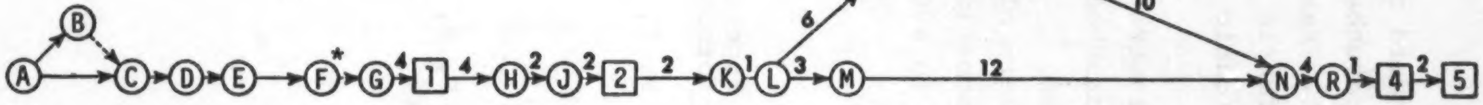
Compliance Schedules - Figures 3-160 and 3-161 illustrate expeditious schedules for installation of a wet scrubber and a fabric filter on a rotary kiln.

Because the industry is seasonal in the northern climates, field construction and control system tie-in are sometimes scheduled only during the winter and early spring to avoid financial hardships caused by shutdown.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, E, C
2.	Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Prepared by Midwest Research Institute for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 203 522. May 1971. 613 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices



* Refer to Chapter 2 for time increments A to G.

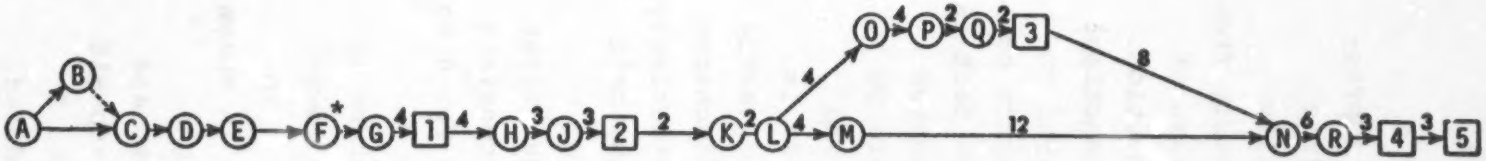
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	27
4	Date by which on-site construction or installation of emission control equipment is completed.	42
5	Date by which final compliance is achieved.	44

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-160. Schedule for installation of a wet scrubber on an asphalt batch plant.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	47
5	Date by which final compliance is achieved.	50

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-161. Schedule for installation of a fabric filter on an asphalt batch plant.

3.8.7 Asphalt Roofing

Process Description - Asphalt roofings are made by impregnating a felt base with asphalt on high-speed machines called asphalt saturators. Figure 3-162 schematically illustrates this process. The felt is fed continuously from rolls onto the dry looper, which provides live storage of felt so that changing rolls will not interrupt production. From the dry looper, the felt travels to the spray section, where liquid asphalt heated to 400 to 450°F is sprayed on one side of the felt; this spraying drives the moisture out of the unsprayed side and prevents blisters when the felt is saturated. In the asphalt tank, the felt is impregnated with asphalt maintained at the designated temperature by continuous circulation through an asphalt heater. The impregnated felt then enters the wet looper, where it is cooled by traveling over sets of rollers arranged in vertical loops. The impregnated felt is rolled at the discharge end of the wet looper for use as roofing felt; alternatively, rock granules or other materials can be added and the felt cut for use as roofing shingles.

At some roofing plants the asphalt saturant must first be processed. This preparation, called "blowing", consists of oxidizing the asphalt by bubbling air through it for 8 to 16 hours.

Atmospheric Emissions - The relatively high temperature at which the asphalt is applied to the felt causes the lower-boiling-point components of the asphalt to vaporize. In addition, moisture in the felt vaporizes, resulting in steam distillation of the asphalt. The vaporized components subsequently condense as very fine particulate matter and create a highly visible plume. Emissions from the asphalt saturation operation without controls range from 1 to 3 pounds of particulate per ton of saturated felt produced.

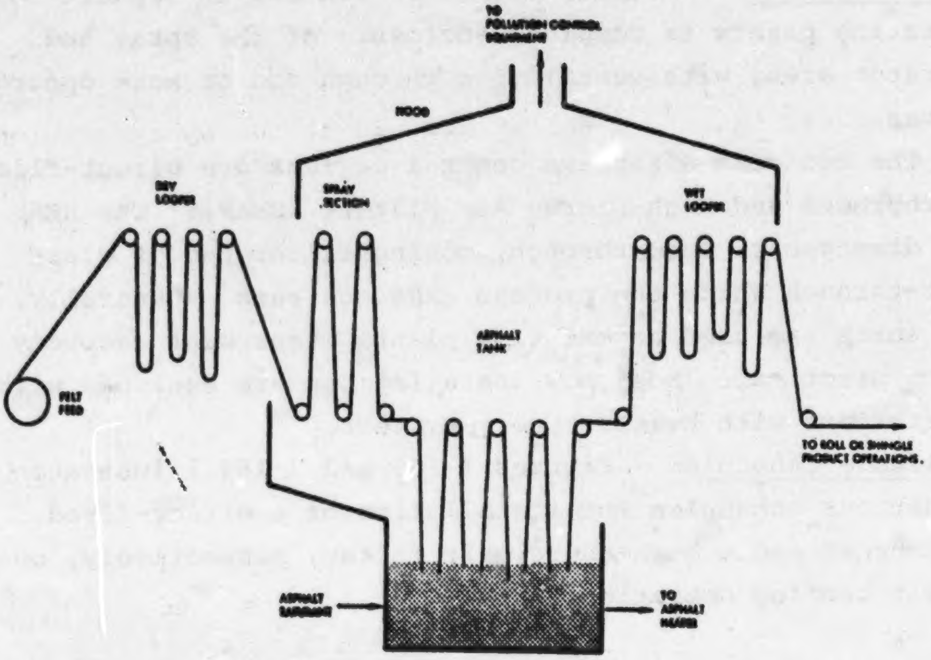

TO POLLUTION CONTROL EQUIPMENT
HOOD
DRY LOOPER
SPRAY SECTION
WET LOOPER
ASPHALT TANK
FELT FEED
TO ROLL OR SHINGLE PRODUCT OPERATIONS.
ASPHALT SATURANT
TO ASPHALT HEATER

Figure 3-162. Manufacture of asphalt roofing materials.

The asphalt blowing operation is another significant source of air pollution. Uncontrolled emissions are approximately 2.5 pounds and 1.5 pounds of particulate and hydrocarbons, respectively, per ton of saturated felt produced.

Control Systems - A common method of control at asphalt saturating plants is complete enclosure of the spray and saturator area, with ventilation through one or more control devices.

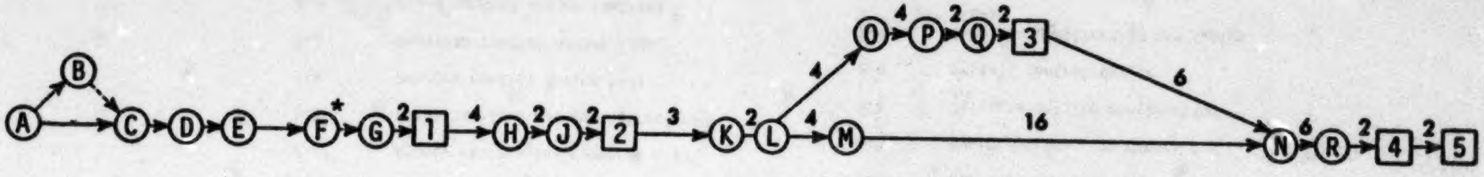
The two most effective control devices are direct-flame afterburners and High-Energy Air Filters (HEAF). The HEAF is a disposable, once-through, moving filter pad of glass fiber through which the process exhausts pass. Generally, HEAF units are used on existing plants where heat recovery is not practical. Most new installations are equipped with afterburners with heat-recovery systems.

Compliance Schedules - Figures 3-163 and 3-164 illustrate expeditious schedules for installation of a direct-fired afterburner and a high-energy air filter, respectively, on an asphalt roofing operation.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, E, C

*P = Process description
E = Emission rates
C = Control devices



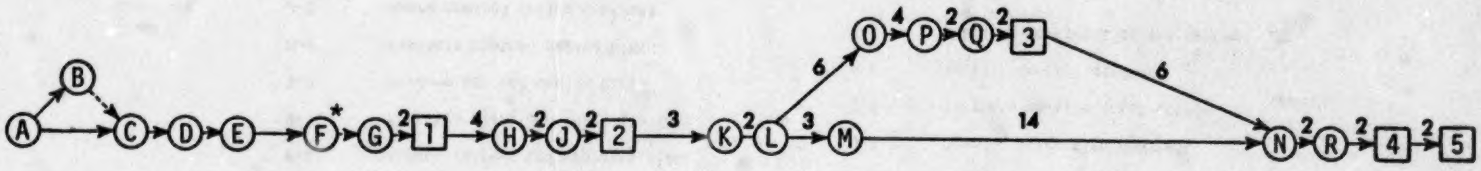
* Refer to Chapter 2 for time increments A to G.

☐ Milestones
→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	27
4	Date by which on-site construction or installation of emission control equipment is completed.	43
5	Date by which final compliance is achieved.	45

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-163. Schedule for installation of an afterburner on an asphalt roofing operation.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones
⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment.	29
4	Date by which on-site construction or installation of emission control equipment is completed.	39
5	Date by which final compliance is achieved.	41

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-164. Schedule for installation of a HEAF unit on an asphalt roofing operation.

3.8.8 Concrete Batching

Process Description - Three types of concrete batching plants are in use: wet-batch plants, central mix plants, and, to a much lesser extent, dry-mix plants. In wet-batch plants the raw materials consisting of sand, aggregates, and cement are mixed in specified proportions and dropped into a transit-mix truck while water is added simultaneously. (See Figure 3-165). In central mix plants the raw materials are mixed at the plant and wet concrete is delivered to the job site in open trucks. In dry-mix plants the sand, aggregate, and cement are mixed dry; the dry mix is transported to the job site, where water is added and the concrete is mixed.

Atmospheric Emissions - Particulates can be emitted in significant quantities from the receiving and conveying of cement, sand, and aggregates, and from load-out of the concrete. Factors affecting the emission rate include the amount and particle size of the materials handled and the type of handling systems. Particulate emissions from an uncontrolled wet-batch plant are approximately 0.2 pound per cubic yard of concrete. The emission potential of dry-mix plants is much higher.

Control Methods - Enclosure of dumping areas and of conveyors and elevators, together with the use of bin vent filters will substantially reduce particulate emissions. Use of wet scrubbers can entail operational difficulties such as plugging of spray nozzles, corrosion, and wastewater disposal problems.

Compliance Schedules - Figure 3-166 illustrates an expeditious schedule for installation of a fabric filter on a concrete batch plant.

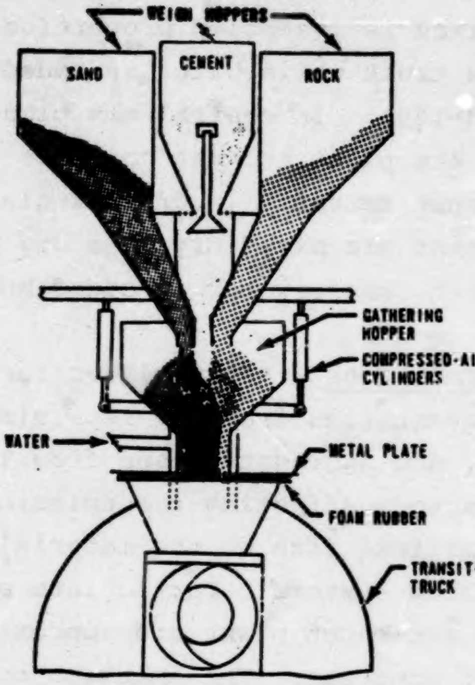
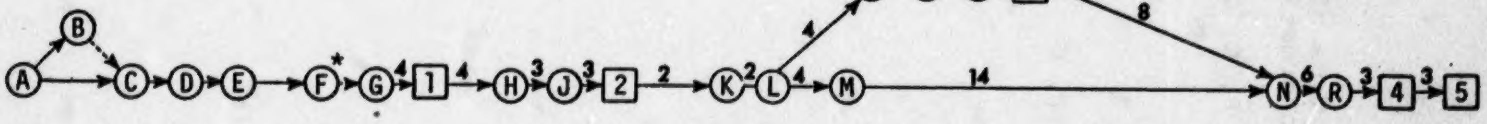

WEIGH HOPPERS
SAND
CEMENT
ROCK
GATHERING HOPPER
COMPRESSED-AIR CYLINDERS
WATER
METAL PLATE
FOAM RUBBER
TRANSIT-MIX TRUCK

Figure 3-165. Wet-concrete batch loading operation.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	30
4	Date by which on-site construction or installation of emission control equipment is completed.	47
5	Date by which final compliance is achieved.	50

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-166. Schedule for installation of a fabric filter on a concrete batch plant.

Sources of Additional Information

	Source	Type of information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-40. May 1973. 987 p.	P, E, C
2.	Exhaust Gases from Combustion and Industrial Processes. Prepared by Engineering-Science, Inc. for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 204-861. October 1971. 436 p.	P, C

*P = Process description
E = Emission rates
C = Control devices

3.8.9 Coal Preparation Plants

Process Description - Coal preparation includes crushing, screening, cleaning, and blending the coal. Some plants only crush and screen the coal and prepare to a specific size. Other preparation plants also clean the coal to reduce the amounts of undersirable materials such as sulfur or ash. Both wet and dry coal cleaning methods are used.

Wet cleaning is based on the differences in specific gravities of the coal and the undesirable materials. Wet separation is done with jigs, dense-medium processes, and concentration tables. After the coal has been separated by a wet technique it is dewatered by screens, followed by centrifuges or vacuum filters. Often, thermal drying by fluidized bed, flash, or multilouvered dryers is required. In dry separation a pulsating air table stratifies the crushed feed into two layers. The coal, being lighter, is removed from the top and sent to storage bins, while the refuse from the bottom is sent to a refuse pile.

Atmospheric Emissions - Thermal dryers and pulsating air tables are the major sources of coal dust emission at coal preparation plants. Crushing, screening, and handling of coal are minor sources of dust emission. Fugitive dust emissions from crushing and screening operations are 0.1 pound of particulate per ton of coal processed.[1] Fluidized bed, multilouver, and flash dryers emit approximately 20, 25, and 16 pounds of particulate, respectively, per ton of coal dried.[2] Approximately 1.3 percent of the dried coal is burned in the thermal dryer.[1] This burning generates combustion gases, which are also emitted to the atmosphere.

Cleaning by pulsating air table eliminates the drying step. The air tables release to the atmosphere approximately 3 pounds of particulate per ton of coal feed.

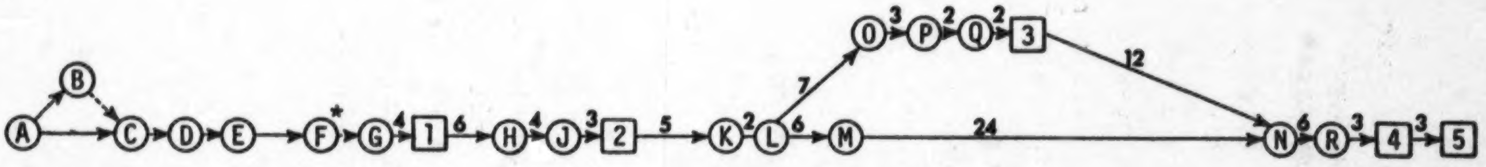
Refuse piles are a source of combustion gas and particulate emissions. Fires can be caused by spontaneous combustion, carelessness, or sabotage. These piles are normally located off-site.

Control Systems - Thermal dryer emissions are normally controlled by mechanical collectors, water sprays, and wet scrubbers. Baghouses are not used because of the danger of a coal dust explosion.[1] High-energy scrubbers with demisters can reduce exhaust grain loadings approximately 99 percent.[3]

Water sprays can reduce crushing emissions approximately 80 percent.[3] Controls are normally not needed on secondary grinding operations because the coal has been completely wetted by water sprays.

For control of emissions from refuse piles, safety measures include proper construction of the pile by compaction and sealing to prevent air circulation and ignition. The refuse pile is not needed if the reject material is used to backfill underground mine tunnels. Proper sealing of the mine eliminates any potential refuse burning.

Compliance Schedules - Figure 3-167 shows an installation schedule for a high-energy wet scrubber. A coal preparation plant may have multiple thermal dryers, located so that more than one scrubber is needed. About 8 weeks is required for each additional scrubber. Installation of one high-energy scrubber will require approximately 64 weeks, including 24 weeks for control device fabrication.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	17
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	63
5	Date by which final compliance is achieved.	66

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-167. Schedule for installation of a high-energy wet scrubber on a coal preparation thermal dryer.

Sources of Additional Information

	Source	Type of information*
1.	Cavanaugh, F.C., et al. Atmospheric Pollution Potential from Fossil Fuel Resource Extraction, On-Site Processing, and Transportation. Prepared by Radian Corporation for U.S. Environmental Protection Agency under Contract No. 68-02-1319, Task 19. March 1976. p. 293.	P, E, C
2.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication AP-42. February 1976. pp. 8.9-1 and 8.9-2.	E
3.	Environmental Assessment of Coal Transportation. Draft report prepared by PEDCo-Environmental Specialists, Inc. for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina under Contract No. 68-02-1321, Task 40. October 1976.	P, E, C

* P = Process description
E = Emission rates
C = Contol devices

3.9 PETROLEUM INDUSTRY

3.9.1 Petroleum Refining

Process Description - Capacities of petroleum refineries normally range from under 20,000 barrels per day to more than 200,000 barrels per day at a complete modern refinery.

Crude oil is initially separated by distillation into boiling-range fractions (e.g., gas, naphtha, kerosene, middle distillates, and heavy bottoms). Since these fractions seldom conform to either product demand or quality requirements, the less desirable fractions are converted to more marketable products. Conversion normally consists of splitting, uniting, or rearranging the original molecular structure. The subsequent separation and conversion products are then treated for removal of undersirable components and are blended with each other and a variety of additives to meet product specifications.

The conversion processes consist of hydro, catalytic-, and thermal-cracking, which function principally to produce smaller, lower-boiling-point hydrocarbons. Catalytic reforming produces higher-quality gasoline mainly by isomerizing and aromatizing naphtha. Polymerization combines two or more gaseous olefins, and alkylation combines an olefin with an isoparaffin to form gasoline-range hydrocarbons. An isomerization unit increases the formation of molecular branch chains and improves gasoline quality. The most common treating processes, such as caustic treating, hydrotreating, and desulfurization, are used to reduce the product's sulfur content.

Figures 3-168 and 3-169 illustrate processing plants for intermediate and complete refineries, respectively.

Atmospheric Emissions - Refinery operations entail a number of emission sources, including storage tanks, wastewater

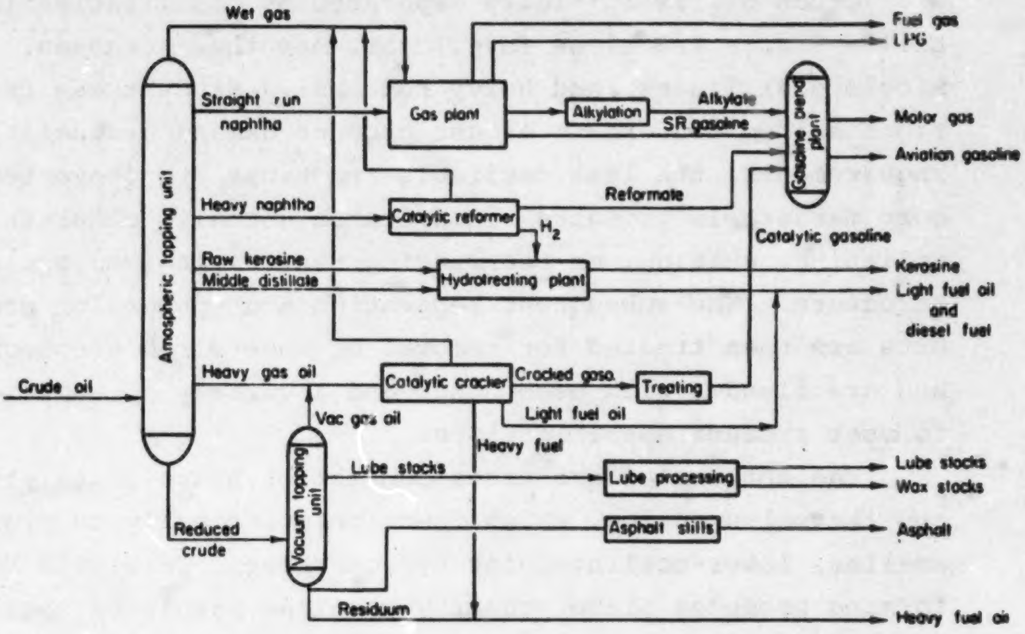

Wet gas
Fuel gas
LPG
Straight run naphtha
Gas plant
Alkylation
Alkylate
SR gasoline
Gasoline blend plant
Motor gas
Aviation gasoline
Reformate
Heavy naphtha
Catalytic reformer
H_2
Catalytic gasoline
Raw kerosine
Middle distillate
Hydrotreating plant
Kerosine
Light fuel oil and diesel fuel
Amospheric topping unit
Crude oil
Heavy gas oil
Catalytic cracker
Cracked gaso.
Treating
Vac gas oil
Light fuel oil
Heavy fuel
Vacuum topping unit
Lube stocks
Lube processing
Lube stocks
Wax stocks
Reduced crude
Asphalt stills
Asphalt
Residuum
Heavy fuel oil

Figure 3-168. Intermediate refinery.

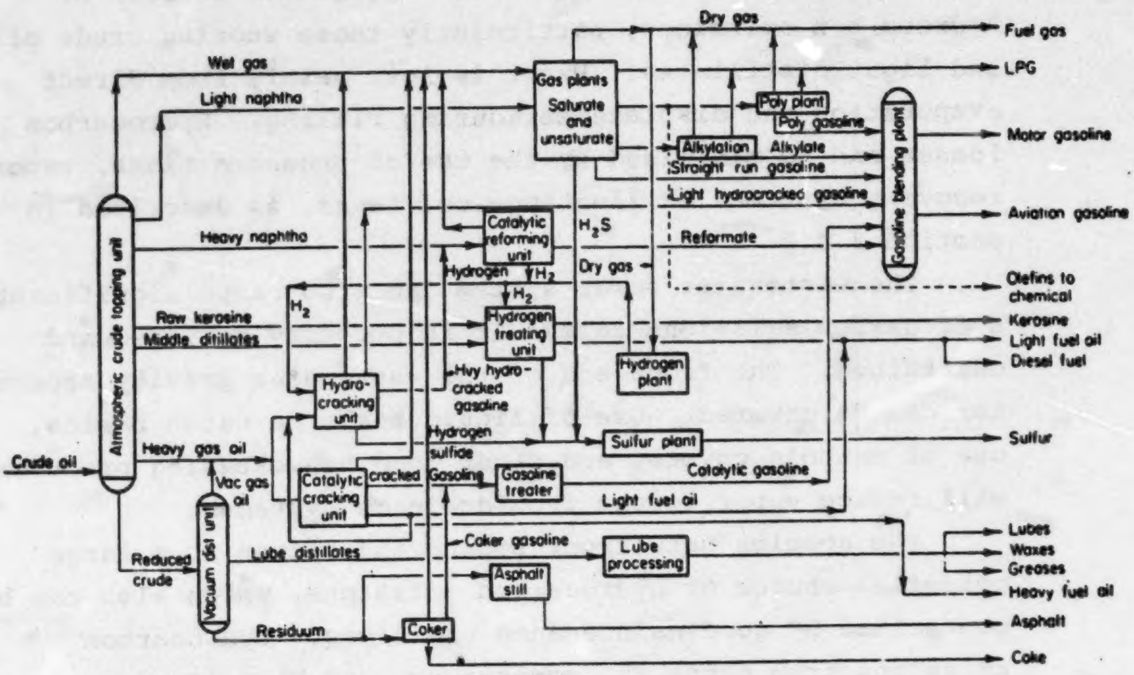

Crude oil
Atmospheric crude topping unit
Wet gas
Light naphtha
Heavy naphtha
Raw kerosine
Middle distillates
H_2
Heavy gas oil
Reduced crude
Vacuum dist unit
Vac gas oil
Lube distillates
Residuum
Dry gas
Gas plants
Saturate and unsaturate
Poly plant
Poly gasoline
Alkylation
Alkylate
Straight run gasoline
Light hydrocracked gasoline
Catalytic reforming unit
H_2S
Reformate
Hydrogen
H_2
H_2
Dry gas
Hydrogen treating unit
Hydrogen plant
Hydro-cracking unit
Hvy hydro-cracked gasoline
Hydrogen sulfide
Sulfur plant
Catalytic cracking unit
cracked
Gasoline
Gasoline treater
Catalytic gasoline
Light fuel oil
Coker gasoline
Lube processing
Asphalt still
Coker
Gasoline blending plant
Fuel gas
LPG
Motor gasoline
Aviation gasoline
Olefins to chemical
Kerosine
Light fuel oil
Diesel fuel
Sulfur
Lubes
Waxes
Greases
Heavy fuel oil
Asphalt
Coke

Figure 3-169. Complete refinery.

sewer systems, pumping systems, blowdown systems, boilers and process heaters, and catalytic regeneration units. Emissions from many of these sources can be effectively controlled by proper design and maintenance.

Storage tanks are significant potential sources of hydrocarbon emissions, particularly those storing crude oil and light distillates. Vapor is lost mainly from direct evaporation and displacement during filling. Hydrocarbon losses can be minimized by the use of pressure tanks, vapor-recovery systems, or floating-roof tanks, as described in Section 3.3.2.

The wastewater sewer system can also cause significant hydrocarbon emissions unless it is properly designed and maintained. The front end of the wastewater gravity separator can be covered. Use of liquid seals on catch basins, use of manhole covers, and other good housekeeping practices will reduce vapor losses from drainage systems.

The complex network of piping and valves is a large potential source of hydrocarbon emissions, which also can be controlled by good maintenance practices. Hydrocarbon emissions from pumps and compressors can be reduced by proper maintenance and the use of mechanical seals in light hydrocarbon service.

Blowdown systems are used during start-up and shutdown of process units to vent hydrocarbon vapors and during routine operation to capture various hydrocarbon leaks and vented materials from relief valves. Condensable hydrocarbons are recovered and the noncondensibles are flared. Emissions can be minimized by use of a properly designed smokeless flare with steam or air injection.

Boiler and process heaters burning heavy fuel oil are a major source of particulates, nitrogen oxides, and sulfur oxides. They can also emit significant quantities of hydrocarbons and aldehydes.

The catalyst regeneration system of the catalytic-cracking unit is a major source of carbon monoxide, sulfur and nitrogen oxides, hydrocarbons, and particulate emissions. In the fluid catalytic cracking unit, the most common type in larger refineries, the catalyst is regenerated in a continuous moving bed to maintain unit heat balance and burn off the coke that is formed on the catalyst surface.

Regeneration of catalyst from fixed bed reforming, hydrotreating, and hydrocracking is normally done in batches during a shutdown. The regeneration consists of burning coke and other deposits off the catalyst with a circulating inert gas stream containing a controlled amount of oxygen. Regeneration of reforming catalyst emits CO_2 and some halides as acid mist. Regeneration of hydrotreating and hydrocracking catalyst emits CO_2, SO_2, ammonia, and other minor impurities.

Control Systems - As mentioned earlier, many emissions may be effectively reduced by proper maintenance or by venting to a vapor recovery or flare system.

Sulfur-laden hydrocarbon vapor streams are normally treated by amine treaters, which yield a recoverable hydrocarbon stream and a stream high in H_2S. Vapor streams rich in H_2S can be controlled by a sulfur plant (Claus Unit) that recovers elemental sulfur; sulfur removal efficiencies of Claus plants are 93 to 99 percent. Several processes are available to reduce the sulfur content of the tail gas from a Claus Unit, some of which treat the tail gas before incineration and some after incineration. The product stream is either elemental sulfur or SO_2. Among the processes available that appear acceptable are the Beavon Sulfur Removal Process, the Clean Air Sulfur Process, the Shell Flue Gas

Desulfurization Process, and the Wellman-Power Gas SO_2 Recovery Process.

Carbon monoxide and hydrocarbon emissions from a fluid catalytic cracking unit can be controlled by waste heat boilers, and particulate emissions, by electrostatic precipitators. Waste heat boilers are normally used on all large units for heat recovery. Multistage cyclones, which are an integral part of the cracking unit, will also reduce the particulate load to the precipitator.

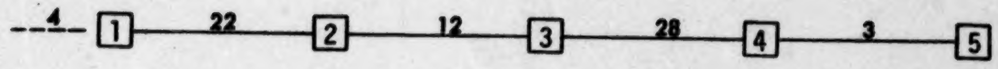
Emissions from regeneration of fixed bed catalyst can be controlled by passing regeneration gases through a caustic scrubber and venting the wet gas to a firebox.

Compliance Schedules - Figures 3-170 through 3-173 illustrate expeditious schedules for installation of an amine treater-sulfur plant, a tail gas desulfurization unit, a package amine treater-sulfur plant, and an electrostatic precipitator. The schedules for tail gas desulfurization represent an average time requirement for the several processes available.

Sources of Additional Information

	Source	Type of Information*
1.	Danielson, J.A., editor. Air Pollution Engineering Manual. U.S. Environmental Protection Agency, Research Triangle Park, III N.C. Publication Number AP-40. May 1973. 987p.	P, E, C
2.	Elkin, H.F. Petroleum Refinery Emissions. In: Air Pollution, Volume III, Stern, A.C. (ed.). Academic Press, New York, 1968. pp. 97-122.	P, C
3.	Nelson, W.L. Petroleum Refinery Engineering. McGraw-Hill, New York, 1958.	P, C
4.	Atmospheric Emissions from Petroleum Refineries. A Guide for Measurement and Control. Public Health Service, Cincinnati, Ohio. NTIS No. PB 198-096. 1960. 64p.	E

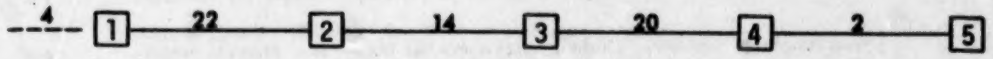
*
P = Process description
E = Emission rates
C = Control devices



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	26
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	66
5	Date by which final compliance is achieved.	69

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

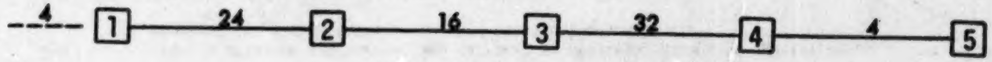
Figure 3-170. Schedule for installation of an amine-treater-sulfur plant at a petroleum refinery.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	26
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	60
5	Date by which final compliance is achieved.	62

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

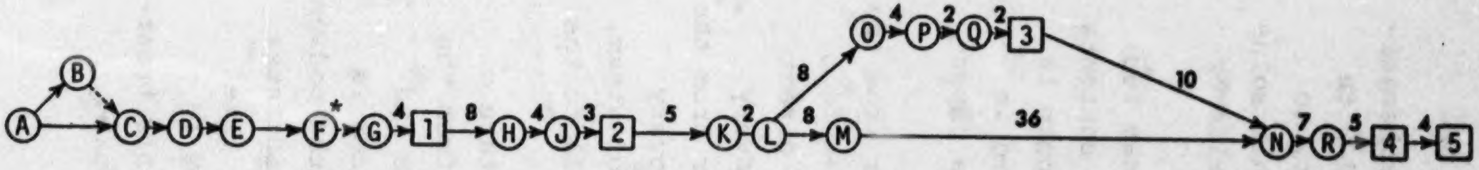
Figure 3-171. Schedule for installation of a tail gas desulfurization unit at a petroleum refinery.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	28
3	Date of initiation of on-site construction or installation of emission control equipment.	44
4	Date by which on-site construction or installation of emission control equipment is completed.	76
5	Date by which final compliance is achieved.	80

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-172. Schedule for installation of an amine treater, a sulfur plant, and a tail gas desulfurization unit at a petroleum refinery.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	42
4	Date by which on-site construction or installation of emission control equipment is completed.	82
5	Date by which final compliance is achieved.	86

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-173. Schedule for installation of an electrostatic precipitator on a catalytic cracking unit.

3.10 PULP AND PAPER

3.10.1 Kraft Process

Process Description - In the Kraft process, shown schematically in Figure 3-174, an aqueous solution is mixed with wood chips in a large pressure vessel, the digester, to dissolve the lignin that binds the wood fibers. This solution, the "white liquor", consists of sodium hydroxide or sodium hydroxide and sodium sulfide.

The mixture is cooked in the digester with steam for several hours. When the cooking is completed, the contents of the digester are forced into a blow tank. The pulp is then separated from the spent "black" liquor, washed in several stages, and bleached before it is sent to a paper mill for further processing.

The spent black liquor together with the water from the pulp washer is initally concentrated in a multiple-effect evaporator. It is usually further concentrated by direct contact evaporation with the flue gas from the recovery boiler. The combustible, concentrated black liquor from the direct contact evaporator is injected into the recovery boiler and burned. Heat is recovered in the form of steam, and the inorganic chemicals in the spent liquor fall to the floor of the furnace in a molten state.

The melt, which consists essentially of a mixture of sodium sulfide and sodium carbonate, is withdrawn from the furnace and dissolved in water and weak liquor from the causticizing plant. The "green" liquor thus produced is further treated with calcium hydroxide to convert the sodium carbonate to sodium hydroxide. The carbonate precipitates from the solution and is collected and sent to the lime kiln. There it is calcined to calcium oxide, which is slaked and converted back to calcium hydroxide. This treatment of the "green" liquor produces the "white" cooking liquor used in the digester.

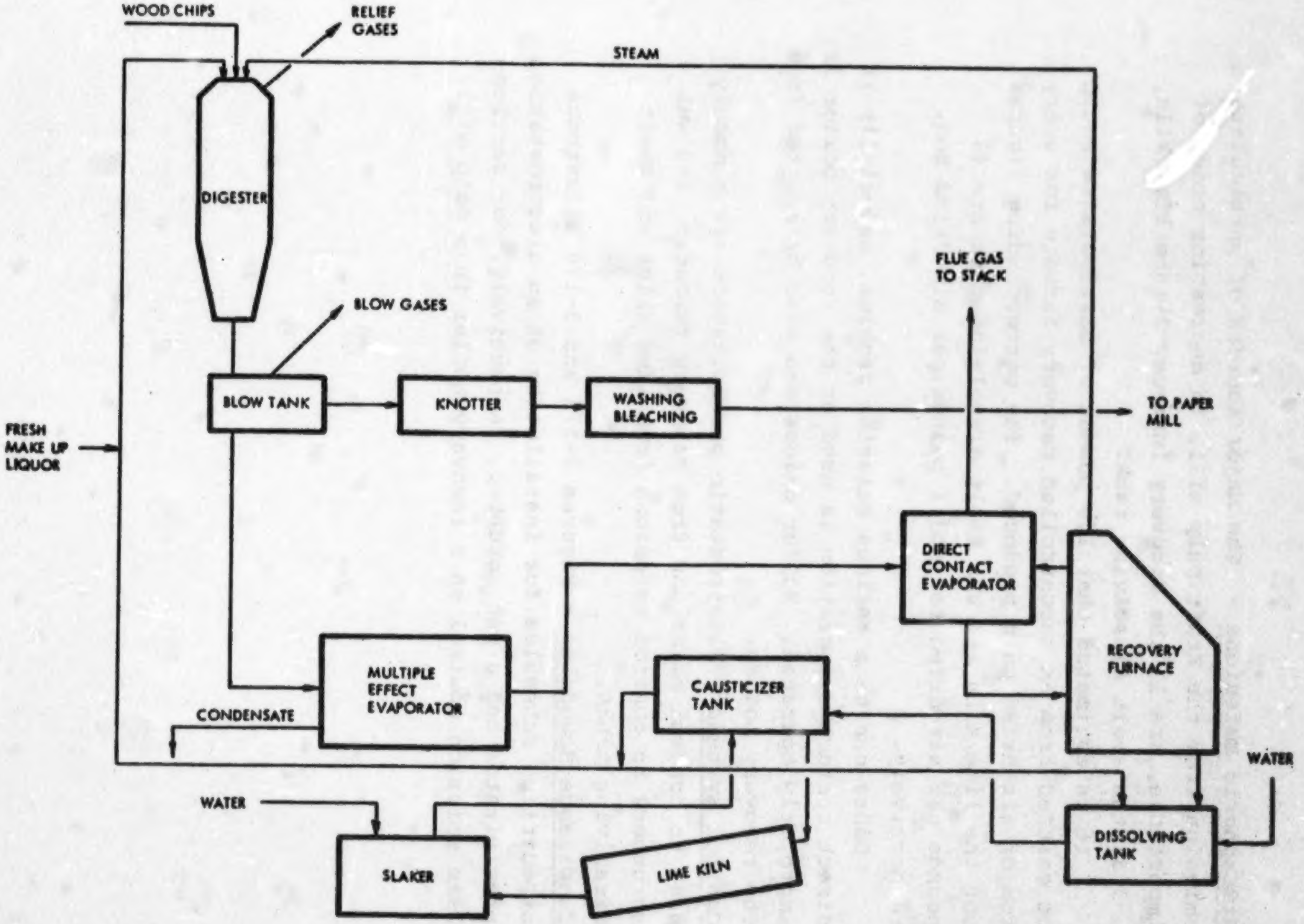

WOOD CHIPS
RELIEF GASES
STEAM
DIGESTER
BLOW GASES
FRESH MAKE UP LIQUOR
BLOW TANK
KNOTTER
WASHING BLEACHING
TO PAPER MILL
FLUE GAS TO STACK
DIRECT CONTACT EVAPORATOR
RECOVERY FURNACE
MULTIPLE EFFECT EVAPORATOR
CONDENSATE
CAUSTICIZER TANK
WATER
SLAKER
LIME KILN
DISSOLVING TANK
WATER

Figure 3-174. Kraft process.

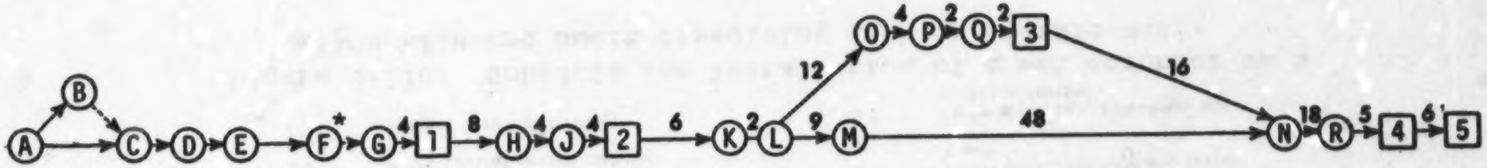
__Atmospheric Emissions__ - The major sources of particulate emission from the Kraft pulp mill, in decreasing order of importance, are 1) the recovery furance, 2) the lime kiln, and 3) the smelt dissolving tank.

It is estimated that 150 pounds of particulates would be emitted from an uncontrolled recovery furnace for every ton of air-dried pulp produced. The corresponding figures for the lime kiln and the smelt dissolving tank are 45 pounds per air-dried ton and 2 pounds per air-dried ton, respectively.

Odors can be a serious emission problem, especially if direct contact evaporation is used or the recovery boiler is improperly operated. Sulfur oxides can also be emitted from the recovery boiler.

__Control Systems__ - Electrostatic precipitators are commonly used to control emissions from recovery furnaces, and wet scrubbers to control emissions from lime kilns and smelt dissolving tanks.

__Compliance Schedules__ - Figures 3-175 and 3-176 illustrate expeditious schedules for installation of an electrostatic precipitator and a wet scrubber, respectively, for particulate emission control on a recovery boiler in a pulp mill.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

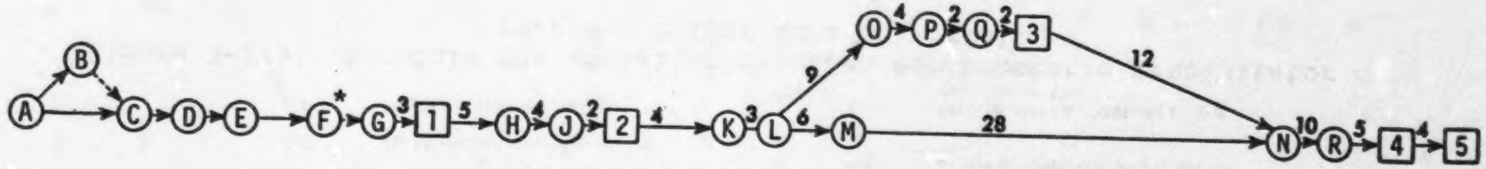
→ Activity and duration in weeks

MILESTONES

		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	20
3	Date of initiation of on-site construction or installation of emission control equipment.	48
4	Date by which on-site construction or installation of emission control equipment is completed.	108
5	Date by which final compliance is achieved.	114

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-175. Schedule for installation of an electrostatic precipitator on a recovery boiler in a pulp mill.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

→ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	14
3	Date of initiation of on-site construction or installation of emission control equipment.	38
4	Date by which on-site construction or installation of emission control equipment is completed.	70
5	Date by which final compliance is achieved.	74

Activity designation	Activity description
A-B	Conduct source tests
A-C	Perform preliminary investigation
C-D	Evaluate control alternatives
D-E	Commit funds for total program
E-F	Prepare control plan and compliance schedule for agency
F-G	Agency reviews and approves plans
G-1	Finalize plans and specifications
1-H	Procure control device bids
H-J	Evaluate control device bids.
J-2	Award control device contract
2-K	Prepare assembly drawings

Activity designation	Activity description
K-L	Review and approve assembly drawings
L-M	Prepare fabrication drawings
M-N	Fabricate control device
L-O	Prepare engineering drawings
O-P	Procure construction bids
P-Q	Evaluate construction bids
Q-3	Award construction contract
3-N	Initiate on-site construction
N-R	Install control device
R-4	Complete construction and system tie-in
4-5	Perform startup, shakedown, and emission testing

Figure 3-176. Schedule for installation of a wet scrubber on a lime kiln and smelt dissolving tank in a Kraft mill.

Sources of Additional Information

	Source	Type of Information*
1.	Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Prepared by Midwest Research Institute for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 203 522. May 1971. 613p.	P, E, C
2.	A Manual of Electrostatic Precipitator Technology. Part II - Application Areas. Prepared by Southern Research Institute for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. NTIS No. 196-387. August 1970. 584p.	C
3.	Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition. Volume 16. Interscience Publishers. New York. 1969.	P
4.	Control of Atmospheric Emissions in the Wood Pulping Industry. Volumes I, II, and III. Prepared by Environmental Engineering, Inc. for the U.S. Environmental Protection Agency. NTIS No. PB 190-351, 190-352, and 190-353. March 1970.	P, E, C

* P = Process description
E = Emission rates
C = Control devices

3.10.2 Sulfite Pulping

Process Description - Pulp mills operating with acid cooking liquor and incorporating no recovery system for spent liquor initially pose a problem of water pollution. Restrictions on the discharge of the spent liquor to surface waters will make mandatory the installation of spent liquor recovery systems at plants that have not already installed such a system. This solution to the water pollution problem, however, can create an air pollution problem. For this reason a control system designed for water treatment also must include air pollution control.

The several commercial systems for treatment of spent sulfite liquor follow basically the same steps: 1) concentration of the dilute spent liquor to a point where it can sustain combustion; 2) burning of the concentrate and recovery of the base chemical and heat; and 3) flue gas quenching and control of sulfur dioxide by scrubbing the gas with a solution containing the recovered base chemical. A simplified flow diagram of the process is shown in Figure 3-177.

Dilute spent sulfite liquor from the pulp washer is sent to a multiple-effect evaporator, where water is driven off and the liquor is concentrated to about 50 percent solids. Some volatile hydrocarbons, such as acetic acid, are also driven off and leave the evaporators with the condensate to enter a water treatment system. The concentrated liquor is combusted in the primary recovery furnace, and steam is generated from the heat of combustion. The recoverable chemical base, such as magnesium, is collected through a multicyclone dry collector or an electrostatic precipitator. If the base is not recoverable, as with ammonia, then no ash collector is needed, since the ammonia

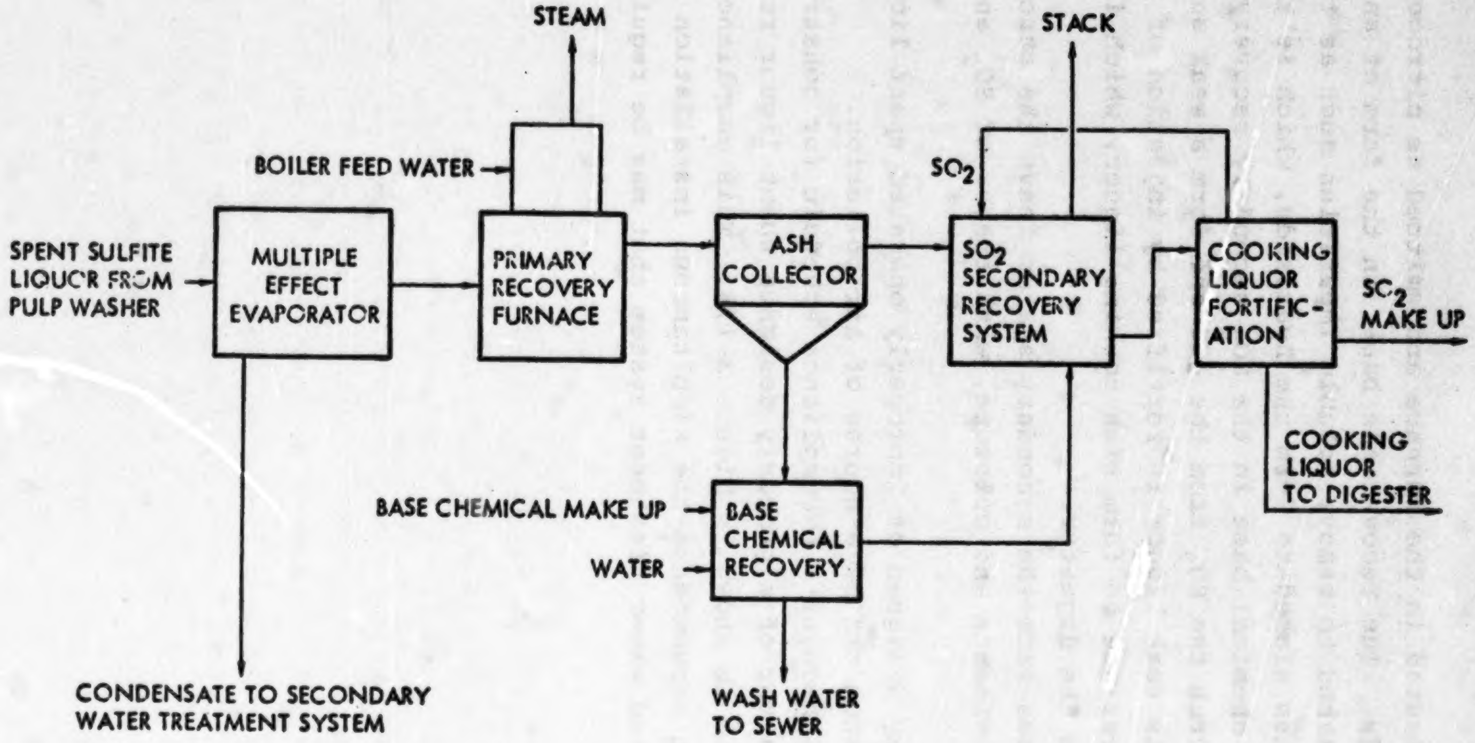

STEAM
STACK
BOILER FEED WATER
SO_2
SPENT SULFITE LIQUOR FROM PULP WASHER
MULTIPLE EFFECT EVAPORATOR
PRIMARY RECOVERY FURNACE
ASH COLLECTOR
SO_2 SECONDARY RECOVERY SYSTEM
COOKING LIQUOR FORTIFICATION
SO_2 MAKE UP
COOKING LIQUOR TO DIGESTER
BASE CHEMICAL MAKE UP
WATER
BASE CHEMICAL RECOVERY
CONDENSATE TO SECONDARY WATER TREATMENT SYSTEM
WASH WATER TO SEWER

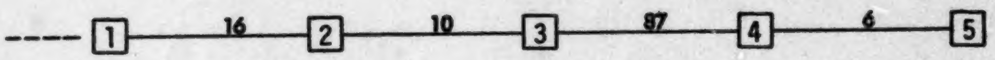
Figure 3-177. Spent sulfite liquor recovery system.

is also combusted in the furnace and emitted as nitrogen and NO_x compounds. The recoverable base, in the form of an oxide, is washed to remove soluble impurities such as the sulfates, then slaked to form the hydroxide, which is then used as the chemical base in the SO_2 secondary recovery system to scrub the SO_2 from the gas and form a weak sulfite liquor. This weak liquor is fortified by injection of SO_2 under low pressure to form rich cooking liquor, which is sent back to the digester.

The gases from the secondary system leave the stack essentially as inerts and moisture, with traces of SO_2 and NO_x.

A poorly designed or improperly operated spent liquor recovery system can be a source of air pollution.

Compliance Schedules - A compliance schedule for construction and startup of a properly designed spent liquor recovery system is shown in Figure 3-178. This compliance schedule can accommodate the simultaneous installation of any associated water treatment system that may be required.



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	0
2	Date of award of control device contract.	16
3	Date of initiation of on-site construction or installation of emission control equipment.	26
4	Date by which on-site construction or installation of emission control equipment is completed.	113
5	Date by which final compliance is achieved.	119

DESIGNATION	ACTIVITY
1-2	Prepare detailed engineering and fabrication drawings, equipment specifications, construction bid documents and award construction contract.
2-3	Fabricate and deliver structural components on site.
3-4	Deliver remaining equipment and complete construction including process tie-ins.
4-5	Perform equipment startup and source testing

Figure 3-178. Schedule for installation of a spent sulfite liquor recovery system in a pulp mill.

Sources of Additional Information

	Source	Type of Information*
1.	Particulate Pollutant System Study. Volume III. Handbook of Emission Properties. Prepared by Midwest Research Institute for the U.S. Environmental Protection Agency, Durham, North Carolina. NTIS No. PB 203 522. May 1971. 613p.	P, E, C
2.	Kirk-Othmer Encyclopedia of Chemical Technology, 2nd edition. Volume 16. Interscience Publishers, New York, 1969.	P
3.	Control of Atmospheric Emissions in the Wood Pulping Industry. Volumes I, II, and III. Prepared by Environmental Engineering, Inc. for the U.S. Environmental Protection Agency. NTIS No. PB 190 351, 190 352, and 190 353. March 1970.	P, E, C

*
P = Process description
E = Emission rates
C = Control devices

3.10.3 Wood Waste (Hog) Boilers

Process Description - Wood waste (hog) boilers are used to dispose of bark and wood scraps and to produce steam. Typically these boilers produce steam at rates of 20,000 to 150,000 pounds per hour. Steam capacities are highly variable, however, and can range from 1000 to 800,000 pounds per hour. The most common hog boilers are spreader stokers; older Dutch oven furnaces and new suspension burning systems are also used to burn the wood waste from Kraft mills. Some wood waste boilers use natural gas, oil, or coal as an auxiliary fuel to maintain or improve combustion and to supplement the wood waste fuel during rapid load transients.[2]

The flyash from hog boilers is primarily unburned carbon and is often reinjected to increase thermal efficiency.

Atmospheric Emissions - Atmospheric discharges from a wood waste boiler contain the gaseous products of combustion and particulate. SO_2 emissions occur only if an auxiliary fuel containing sulfur is used. Except for the sulfur oxide content, the exhaust gas composition is similar to that of a coal-fired boiler. It will contain less moisture and less flyash, depending on the type of bark fired.

Uncontrolled particulate emissions from hog boilers with no flyash reinjection are estimated to be 30 to 50 pounds per ton of bark burned, assuming an as-fired moisture content of 50 percent. Particulate emissions from boilers using flyash reinjection are estimated to be 45 to 75 pounds per ton of fuel.[1]

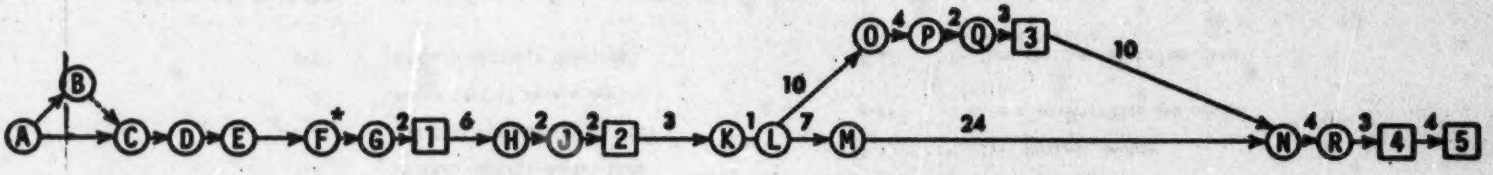
A major factor affecting uncontrolled particulate emissions from boilers using reinjection is the completeness of separation of the sand and other noncombustibles from the flyash before reinjection.

Carbon monoxide and hydrocarbons may be emitted in significant amounts under poor operating conditions.

Control Systems - Most bark boilers are equipped with multiple cyclones with collection efficiencies ranging from 85 to 95 percent. Because this range of efficiencies is not sufficient to meet most state regulations, secondary control devices must be added. Scrubbers, electrostatic precipitators, and fabric filters are capable of attaining the required efficiencies. Fabric filters are not used extensively because of high operating costs, fire hazards, and danger of boiler shutdowns due to tearing and blinding of bags. Although ESP's are used to control hog boilers, the resistivity properties of the flyash may prevent adequate collection unless chemical conditioning agents are added. Scrubbers can provide the required particulate collection efficiency (95 to 98 percent) and are not affected by flyash resistivity.

There is no requirement for absorption of gaseous pollution in a well-operated boiler because the bark feed contains little sulfur and most boilers use natural gas as an auxiliary fuel.

Compliance Schedules - Figures 3-179 and 3-180 illustrate expeditions schedules for installation of a wet scrubber and electrostatic precipitator for control of wood waste (hog) boilers. If water treatment facilities are needed, they can be installed concurrently with the scrubber within the same time interval.



* Refer to Chapter 2 for time increments A to G.

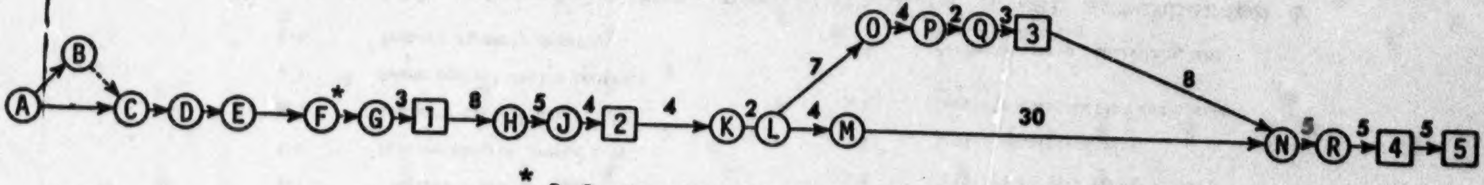
☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	12
3	Date of initiation of on-site construction or installation of emission control equipment.	35
4	Date by which on-site construction or installation of emission control equipment is completed.	54
5	Date by which final compliance is achieved.	58

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-179. Schedule for installation of a wet scrubber on a wood waste (hog) boiler.



* Refer to Chapter 2 for time increments A to G.

☐ Milestones

⟶ Activity and duration in weeks

MILESTONES		ELAPSED TIME FROM G, WEEKS
1	Date of submittal of final control plan to appropriate agency.	3
2	Date of award of control device contract.	20
3	Date of initiation of on-site construction or installation of emission control equipment.	42
4	Date by which on-site construction or installation of emission control equipment is completed.	70
5	Date by which final compliance is achieved.	75

Activity designation	Activity description	Activity designation	Activity description
A-B	Conduct source tests	K-L	Review and approve assembly drawings
A-C	Perform preliminary investigation	L-M	Prepare fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare control plan and compliance schedule for agency	O-P	Procure construction bids
F-G	Agency reviews and approves plans	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	Initiate on-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction and system tie-in
2-K	Prepare assembly drawings	4-5	Perform startup, shakedown, and emission testing

Figure 3-180. Schedule for installation of electrostatic precipitator on a wood waste (hog) boiler.

Sources of Additional Information

	Source	Type of information*
1.	Compilation of Air Pollutant Emission Factors, 2nd edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. AP-42. February 1976.	E
2.	Junge, David C. Boiler Fired with Wood and Bark Residues. Prepared by Forest Research Laboratory, Oregon State University for Plywood Research Foundation. November 1975. 59 p.	P, E, C
3.	Hardison, L.C. and C.A. Greathouse. Air Pollution Control Technology and Costs in Nine Selected Areas. Prepared by Industrial Gas Cleaning Institute for U.S. Environmental Protection Agency. September 1972. pp. 317-348.	P, E, C

*
P = Process description
E = Emission rates
C = Control devices

4.0 SUPPORTING DATA

Information on compliance schedules was obtained from control equipment suppliers, equipment users, and from a survey conducted by the Industrial Gas Cleaning Institute (IGCI). Supplementary information was also obtained from compliance schedules submitted to control agencies by various companies. These data sources were then combined into the generalized schedules presented in this document. Obviously a wide range of time increments were encountered due to the size variations in the control equipment and the many site specific conditions encountered in past installations. A great deal of judgement was thus required to arrive at a single schedule.

4.1 INFORMATION FROM EQUIPMENT SUPPLIERS

Tables 4-1 and 4-2 summarize information obtained from equipment suppliers or vendors for large and small electrostatic precipitators. The largest variations in individual time increments occur in the fabrication and engineering drawing phase and the actual fabrication and erection phases.

Table 4-3 presents similar information for wet scrubbers of various sizes. Field erection is the most variable single factor. Smaller sized package units require considerably less time in all activities.

Multiple cyclones are relatively uncomplicated devices and thus require less time to fabricate and install. Table 4-4 presents the time ranges estimated by 5 equipment suppliers.

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Table 4-1. VENDOR DELIVERY SCHEDULE FOR INSTALLATION OF LARGE ELECTROSTATIC PRECIPITATOR

(weeks)

Vendor	Equipment size,[a] cfm	Proposal preparation	Assembly drawings	Fabrication drawings	Engineering drawings	Fabrication	Erection	Debugging	Initial operation and testing
1		4-6	10-16			65-104			
2		2-6		8 months		18	26-52		
3		6-7	4-6	6-8		44	26-52		
4	up to 500,000	6	4	20	20	25	30		
	500,000 to 1,000,000	6-8	4	28	28	40	52		
5		4	6-10			16-32	8-52		

[a] For any size unless indicated.

Table 4-2. VENDOR DELIVERY SCHEDULE FOR INSTALLATION OF SMALL ELECTROSTATIC PRECIPITATORS

(weeks)

Vendor	Equipment size,[a] cfm	Proposal preparation	Assembly drawings	Fabrication drawings	Engineering drawings	Fabrication	Erection	Debugging	Initial operation and testing
3		4-5	4-6	←6-8→					
9	up to 200,000	8	4-8	16-20	12-16	35-44	18-26	2-6	2
	more than 200,000	8	4-8	16-20	12-16	35-44	26-52	4-8	4
10		6	6-8	11-12	11-12	24-30	12-20	3	1

[a] For any size unless indicated.

Table 4-3. VENDOR DELIVERY SCHEDULE FOR INSTALLATION OF WET SCRUBBERS

(weeks)

Vendor	Equipment size,[b] cfm	Proposal preparation	Assembly drawings	Fabrication drawings	Engineering drawings	Fabrication	Erection	Debugging	Initial operation and testing
7	up to 200,000	8	4-6	18-22	16-18	18-22	26	4	4
	200,000 to 1,000,000	8	4-6	18-22	16-18	30-34	40-52	4	4
15[a]		1-4	3-8			10-12	6-18		
8	up to 50,000[c]	1-3	1-3	1-4		8-16	2-6	0-4	0-12

[a] Industrial operations only.
[b] For any size unless indicated.
[c] Standard equipment.

Table 4-4. VENDOR DELIVERY SCHEDULE FOR INSTALLATION OF MULTIPLE CYCLONES

(weeks)

Vendor	Equipment size,[b] cfm	Proposal preparation	Assembly drawings	Fabrication drawings	Engineering drawings	Fabrication	Erection	Debugging	Initial operation and testing
11		1-2[c]	2-6	3-4	2-4	5-10	1-4[c]	1	0.5
6[a]		4-8	3-6	8-10		8-10			
12						6-24			
13		1	1	2	2	6-8	3	←1→	
14		1-2	0.2	0.2	1	1-3	1-4	←1→	

[a] For coal fired boiler applications.

[b] For any size unless indicated.

[c] For custom-made equipment to handle large volumes.

Fabric filter installation time supplied by two suppliers are summarized in Table 4-5. The larger systems require considerably more fabrication and erection time, but the other time increments do not vary greatly with equipment size.

Information on molecular sieve installations for gaseous emission controls was supplied as shown in Table 4-6. Considerable variations in time increments, especially in fabrication and erection is evident.

Afterburner delivery and installation schedules as shown in Table 4-7 are fairly consistent between various suppliers.

Mist eliminators for industrial operations are largely shop assembled units and thus do not require extensive engineering or assembly drawing times as shown in Table 4-8.

Schedules for installing a double absorption system at a sulfuric acid plant are shown in Table 4-9. Time variations in the early phases of the work involve different degrees of detail in the planning steps. The balance of the design, fabrication, and installation times are relatively consistent between the two suppliers.

4.2 INFORMATION FROM INDUSTRIAL GAS CLEANING INSTITUTE

Through a separate contract with the Industrial Gas Cleaning Institute, Inc. (IGCI)[+], EPA obtained information from selected air pollution control equipment manufacturers on the time schedules involved in designing and installing control devices. The results of this survey are summarized in Table 4-10 which shows both typical time increments and the range associated with each increment.

This survey was conducted after other compliance schedule information had been obtained, and was used to check this previous information. In most cases, the overall

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[+] EPA Contract 68-02-1473, Task No. 24.

Table 4-5. VENDOR DELIVERY SCHEDULE FOR INSTALLATION OF FABRIC FILTER SYSTEMS

(weeks)

Vendor	Equipment size,[a] cfm	Proposal preparation	Assembly drawings	Fabrication drawings	Engineering drawings	Fabrication	Erection	Debugging	Initial operation and testing
16		←2-4→	2-10[b] →	←2-10[b]	→	8-10[b]	4-10[b]		
17	up to 200,000	3	4-5	16-20	26-30	14-16	4	1-2	1
17	200,000 to 500,000	4	4-5	16-20	26-30	40-44	14-18	2	1

[a] For any size unless indicated.

[b] Use upper range for custom made equipment.

Table 4-6. VENDOR DELIVERY SCHEDULE FOR INSTALLATION OF MOLECULAR SIEVE

(weeks)

Vendor	Equipment size,[a] cfm	Proposal preparation	Assembly drawings	Fabrication drawings	Engineering drawings	Fabrication	Erection	Debugging	Initial operation and testing
18		2	←	14	→	← 52	→	← 8-10	→
19		3-4	3-4	4		8-10			
20					14-18		14	4	1

[a] For any size unless indicated.

Table 4-7. VENDOR DELIVERY SCHEDULE FOR INSTALLATION OF AFTERBURNER

(weeks)

Vendor	Equipment size,[a] cfm	Proposal preparation	Assembly drawings	Fabrication drawings	Engineering drawings	Fabrication	Erection	Debugging	Initial operation and testing
21[b]		2-3	6-8			14-16			
22		2-4	15			12-26	8	1	1
23[b]		1-2	3		10	13-16	2-3	1-2	
24		2	7-8			16-20	6	2	1

[a] For any size unless indicated.

[b] Vendor does not provide customer with fabrication drawings.

Table 4-8. VENDOR DELIVERY SCHEDULE FOR INSTALLATION OF MIST ELIMINATOR ON AN INDUSTRIAL OPERATION

(weeks)

Vendor	Equipment size,[a] cfm	Proposal preparation	Assembly drawings	Fabrication drawings	Engineering drawings	Fabrication	Erection	Debugging	Initial operation and testing
25[b]		3	2	3	3	8	c		
26	2,000 or below	1	1	1	1	2	c		
27	4,200 (3' dia., 6" mesh pad)					d	0.2		
27	47,000 (10' dia., 6" mesh pad)					d	1		
28						6	c		

[a] For any size unless indicated.

[b] Time schedules do not vary with size.

[c] Vendor does not provide installation and erection services.

[d] Vendor does not manufacture equipment.

Table 4-9. VENDOR DELIVERY SCHEDULE FOR INSTALLATION OF DUAL ABSORPTION SYSTEM FOR SULFURIC ACID PRODUCTION

(weeks)

Vendor	Equipment size,[a] cfm	Proposal preparation	Assembly drawings	Fabrication drawings	Engineering drawings	Fabrication	Erection	Debugging	Initial operation and testing
29		1-2[b] 6-8[c] 18-20[d]		104-130					
30		12-14[e]		13	43	40-52	52	2	2

[a] For any size unless indicated.
[b] For providing cost estimations with a variation of 20 percent.
[c] For providing cost estimations with a variation of 15 percent.
[d] For providing cost estimations with a variation of 5 percent.
[e] For providing cost estimations with a variation of 10 percent.

Table 4-10. SUMMARY OF COMPLIANCE SCHEDULE DATA FROM IGCI SURVEY

		Electrostatic Precipitators						Fabric Filters					
		<300,000 acfm gas flow			>300,000 acfm gas flow			<200,000 acfm gas flow			>200,000 acfm gas flow		
Designation	Activity Description	Typical time, weeks	Range, weeks	Milestone, weeks	Typical time, weeks	Range, weeks	Milestone, weeks	Typical time, weeks	Range, weeks	Milestone, weeks	Typical time, weeks	Range, weeks	Milestone, weeks
G-1	Finalize plans and specifications	4	3-7	4	5	4-6	5	5	3-6	5	5	2-6	5
1-H	Procure control device bids	4	3-4		7	6-8		6	2-6		6	2-8	
H-J	Evaluate control device bids	4	3-8		10	10-12		3	1-4		4	2-6	
J-2	Award control device contract	3	2-4	11	3	2-4	20	2	1-2	11	4	2-4	14
2-K	Prepare assembly drawings (vendor)	7	4-10		10	6-14		4	2-8		7	4-8	
K-L	Review and approve assembly drawings	5	4-6		6	4-8		2	2-4		3	2-6	
L-M	Prepare fabrication drawings (vendor)	17	8-24		20	14-24		5	1-12		11	4-20	
M-N	Fabricate control device	23	10-52		43	20-104		11	4-24		22	12-36	
L-O	Prepare engineering drawings for system	10	-		22	15-30		6	1-12		10	8-16	
O-P	Procure construction bids	6	-		6	-		2	2-4		4	2-6	
P-Q	Evaluate construction bids	2	-		3	-		2	1-2		3	1-6	
Q-3	Award construction contract	2	-	32	2	-	49	1	1-2	17	2	1-4	29
3-N	Perform on-site construction	21	16-24		67	24-125		6	1-12		13	6-24	
N-R	Install control device	5	2-8		19	1-70		4	2-10		12	6-20	
R-4	Complete construction (system tie-in)	2	1-2	28	4	1-4	90	2	1-6	12	5	3-6	30
4-5	Start-up, shake down prel. source-test	3	1-4	3	8	3-10	8	3	1-4	3	4	2-8	4
Total time via fabrication path		77	38-120		135	71-264		47	20-86		83	39-128	
Total time via construction path		78	36-86	78	172	87-302	172	48	21-82	48	82	43-128	82

Table 4-10 (continued). SUMMARY OF COMPLIANCE SCHEDULE DATA FROM IGCI SURVEY

		Wet Scrubbers									Flue Gas		
		Low-Energy <150,000 acfm gas flow			High-Energy <150,000 acfm gas flow			High-Energy >150,000 acfm gas flow			Desulfurization System Limestone Scrubbing		
Designation	Activity Description	Typical time, weeks	Range, weeks	Milestone, weeks	Typical time, weeks	Range, weeks	Milestone, weeks	Typical time, weeks	Range, weeks	Milestone, weeks	Typical time, weeks	Range, weeks	Milestone, weeks
G-1	Finalize plans and specifications	3	2-5	3	3	2-5	3	3	2-5	3	6	2-10	6
1-H	Procure control device bids	4	2-6		4	2-6		5	2-8		10	6-20	
H-J	Evaluate control device bids	2	2-4		3	2-4		4	2-5		7	2-26	
J-2	Award control device contract	2	2-4	8	2	2-4	9	2	2-4	11	2	1-8	19
2-K	Prepare assembly drawings (vendor)	3	2-6		4	2-10		5	2-10		21	6-39	
K-L	Review & approve assembly drawings	3	2-4		3	2-4		4	2-5		5	2-10	
L-M	Prepare fabrication drawings (vendor)	6	3-7		6	4-8		6	5-8		21	8-34	
M-N	Fabricate control device	15	12-24		22	12-40		28	17-48		58	8-79	
L-O	Prepare engineering drawings for system	8	4-10		7	4-12		9	8-12		20	3-52	
O-P	Procure construction bids	4	2-5		4	2-5		4	2-5		5	2-12	
P-Q	Evaluate construction bids	2	1-3		2	1-3		2	1-3		5	2-12	
Q-3	Award construction contract	1	1-3	21	1	1-3	21	2	2-3	26	2	1-5	58
3-N	Perform on-site construction	7	6-10		10	8-15		13	10-18		55	15-90	
N-R	Install control device	3	2-6		7	1-14		10	4-20		10	4-30	
R-4	Complete construction (system tie-in)	3	1-6	13	4	1-6	21	5	2-8	28	8	2-26	73
4-5	Start up, shake down prel. source test	4	2-5	4	4	3-5	4	4	3-6	4	6	2-20	6
Total time via fabrication path		48	32-77		61	33-106		76	43-127		156	60-242	
Total time via construction path		49	31-77	49	58	33-96	58	72	44-112	72	162	77-286	162

schedules were in the range obtained in the IGCI survey. Individual activities did not always agree with the IGCI estimates and adjustments were made in the previously obtained information.

APPENDIX A
BASIC CONVERSION FACTORS

APPENDIX A. BASIC CONVERSION FACTORS

Length				
Units		cm	m	
1 in.	=	2.54	0.0254	
1 ft	=	30.48	0.3048	
1 yd	=	91.44	0.9144	
1 mile	=	1.609344×10^5	1.609344×10^3	
Area				
Units		cm^2	m^2	
1 $in.^2$	=	6.4516	6.4516×10^{-4}	
1 ft^2	=	929.0304	0.09290304	
1 yd^2	=	8361.273	0.8361273	
1 $mile^2$	=	2.589988×10^{10}	2.589988×10^6	
Volume				
Units		cm^3	liter	
1 $in.^3$	=	16.38706	0.01638706	
1 ft^3	=	28316.85	28.31685	
1 qt	=	946.353	0.946353	
1 gal (U.S.)	=	3785.412	3.785412	
Mass				
Units		g	kg	Metric ton
1 oz (avdp)	=	28.34952	0.02834952	
1 lb (avdp)	=	453.5924	0.4535924	
1 ton	=	907184.7	907.1837	0.9071847
Energy				
Units		Btu	kWh	
1 cal	=	3.965667×10^{-3}	$1.1622222... \times 10^{-6}$	